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# National Assessment of the Urban Particulate Problem. Volume XIII San Francisco, California

GCA Corp, Bedford, Mass GCA Technology Div

Prepared for

Environmental Protection Agency, Research Triangle Park, N C Office of Air Quality Planning and Standards

Jun 76

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# NATIONAL ASSESSMENT OF THE URBAN PARTICULATE PROBLEM

## Volume XIII - San Francisco

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16. ABSTRACT


This document is one volume of a sixteen-volume report presenting an overall assessment of the particulate problem, which was conducted by GCA/Technology Division for EPA.

This particular document is one of fourteen single-area volumes that provide working summaries of data gathered in the fourteen urban areas studied. These city reports primarily provide documentation and background information for Volume I of the study - National Assessment of the Particulate Problem - Final Report. Volume I should be considered the primary output of the report.


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|---|---|---|
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# NATIONAL ASSESSMENT OF THE URBAN PARTICULATE PROBLEM

*Volume XIII*
*San Francisco, California*

FINAL REPORT

by

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Prepared for

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Research Triangle Park, North Carolina 27711

June 1976

This final report was furnished to the Environmental Protection Agency by the GCA/Technology Division in fulfillment of the requirements under Contract No. 68-02-1376, Task Order No. 18. The contents of this report are reproduced herein as received from the contractor. The opinions, findings and conclusions are those of the authors and not necessarily those of the Environmental Protection Agency.

## FOREWORD

This document is part of a 16-volume report assessing the urban particulate problem, which was conducted by GCA/Technology Division for EPA.

This particular document is one of the 14 single city volumes that provide working summaries of data gathered in the 14 urban areas during 1974 to support an assessment of the general nature and extent of the TSP problem nationwide. No attempt was made to perform detailed or extensive analyses in each urban area. Rather, the city reports are intended as a collection of pertinent data which collectively form a profile of each urban area. This, in turn contributes to a comparative analysis of data among the 14 areas in an attempt to identify general patterns and factors relating to attainment of the TSP problem nationwide. Such an analysis has been made in Volume I of the study-National Assessment of the Urban Particulate Problem-National Assessment. The reader is referred to this volume as the summary document where the data is collectively analyzed.

This and the other 13 city reports are viewed primarily as working documents; thus, no effort was made to incorporate all the reviewer's comments into the text of the report. The comments were, however, considered during the preparation of Volume I and are included herein in order to alert the reader to different points of view. The 16 volumes comprising the overall study are as follows:

| | | |
|---|---|---|
| Volume | I | = National Assessment of the Urban Particulate Problem |
| Volume | II | = Particle Characterization |
| Volume | III | = Denver |
| Volume | IV | = Birmingham |
| Volume | V | = Baltimore |
| Volume | VI | = Philadelphia |
| Volume | VII | = Chattanooga |
| Volume | IX | = Oklahoma City |
| Volume | X | = Seattle |
| Volume | XI | = Cincinnati |
| Volume | XII | = Cleveland |
| Volume | XIII | = San Francisco |
| Volume | XIV | = Miami |
| Volume | XV | = St. Louis |
| Volume | XVI | = Providence |

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## EXECUTIVE SUMMARY

The report summarized herein presents the analyses of the particulate situation in the San Francisco Bay Area conducted as part of the study for the national assessment of the problem of attainment or nonattainment of the National Ambient Air Quality Standards for total suspended particulates (TSP). The San Francisco area, specifically the Bay Area Air Pollution Control District, represents a lightly industrialized area with a complex topography, less than average heating requirements and little precipitation occurring mainly in the winter, that has had some success in reducing emissions and particulate concentrations. Currently the primary standards are being met throughout the District with fugitive dust being a problem at one site.

Analyses of air quality levels and trends, emissions, regulations and surveillance procedures, the TSP monitoring network, and meteorology are included in this report. The major findings in each of these areas are summarized below in the order in which they appear in the text.

### AIR QUALITY

Long term trends in TSP levels at the National Air Sampling Network (NASN) monitors have been primarily down over the past 18 years. Of those 17 monitors currently operating in the District and reporting a full year of data, the national primary annual air quality standard for particulates (75 $\mu g/m^3$) was exceeded at no station and the secondary annual guideline (60 $\mu g/m^3$) was exceeded at two stations. The highest annual geometric mean was 74 $\mu g/m^3$ recorded at a station highly influenced by fugitive dust;

the other station violating the secondary annual standard had a geometric mean of 62 $\mu g/m^3$ in 1974. No site violated the primary 24 hour standard (260 $\mu g/m^3$) more than once and only 24 of the over 1800 observations recorded in 1974 exceeded the secondary 24-hour standard (150 $\mu g/m^3$). Background TSP concentrations from the ocean are probably around 10 $\mu g/m^3$.

The levels of particulates generally average about 30 percent higher in the peak month of September than in the winter months. This pattern is felt to be primarily a result of the meteorology.

EMISSIONS

The District is a lightly industrialized area with many of the major point sources located away from the centers of population. This distribution of sources makes for a fairly low emission density when calculated on a countywide basis. Because of the densely packed population and its small size, San Francisco has the highest emission density of over 850 lbs/day/sq. mi.; emission densities in other counties range from 16 to 91 lbs/day/sq. mi.

Long term trends in total annual particulate emissions in the BAAPCD shows a decline of about 40 percent from the highest point in the late 1950's. Much of this decrease has come since 1969 due to major reductions in emissions from industrial processes and the burning of materials. Emissions from fuel consumption and transportation have maintained a slow increase with further growth in emissions from fuel combustion expected due to natural gas shortages. The Districtwide total daily emission rate was projected to be 170 tons in 1974. The total contribution from industry is approximately half of the emissions in the District.

REGULATIONS AND SURVEILLANCE

The sources in the Bay Area are controlled by regulations from the BAAPCD except for mobile sources which are under the control of the State of California Air Resources Board. The BAAPCD regulations for control of

emissions from industrial processes are comparable to the average of the process weight rate regulations in the 14 cities studied. The control of emissions from fuel burning equipment is more stringent for small sources but less stringent for large sources. While the particulate regulations are not the most stringent of those observed in the course of this study, they seem appropriate given the degree of the TSP problem in the District. The only possible area of difficulty noted was in the lack of a specific fugitive dust regulation which may be needed in the arid climate.

A review of the BAAPCD enforcement activities indicated that a quite active program exists in the area, maintaining complete and up-to-date files on most sources in the area. Surveillance is conducted by 40 inspectors in the field patrolling assigned territories and through plant inspections scheduled by computer on the basis of pollution potential. With respect to the enforcement program, care must be taken to not ignore particulate sources for the sake of controlling sources of organics and other pollutants which are a more serious problem in the Bay Area.

Most all sources in the District have been determined to be in compliance with respect to particulate matter. While most of these determinations are made through calculations of input and operating parameters, within the past couple of years final compliance of larger sources has been checked primarily through source tests. The Source Test Section of the BAAPCD conducts 300 to 400 tests at smoke stacks and other emission points each year.

NETWORK DESIGN

The network reviewed was found to be generally well designed in terms of neighborhood selection and monitor siting. The monitoring network for the District is designed to identify the TSP concentrations (and other pollution levels) to which the general population is exposed; therefore, most

monitors are located in areas classified as center city-commercial whereas four stations are in industrial areas.

Specific problems were noted at two monitor sites for which the ventilation characteristics were deemed inappropriate. One site (San Francisco) was located in a semi-enclosed area up against a seven story building; the other site (Richmond) was suspended in the corner of a gravel roof.

There was some difficulty in evaluating the air quality data in relation to emissions partly because of the low density of monitors in the BAAPCD. While the number of monitors is sufficient to meet federal requirements, the density of monitors was the lowest of the areas studied. This is likely the result of the data to date which illustrates the lack of any major problem with TSP in the District. Recent efforts at developing a model for the area should help in determining if additional sites are needed.

METEOROLOGY AND CLIMATOLOGY

Since particulates are emitted at a fairly constant rate throughout the year, the fluctuations in the ambient levels are primarily a result of the meteorology. The strong seasonal pattern of high TSP levels in the summer to fall and lower values in the winter and spring results from the pattern of ventilation and precipitation in the area.

Characteristics of the ventilation in the District are tabulated daily by the BAAPCD and summarized monthly. The measure of stability for vertical mixing and the total ventilation (ventilation index) both tend to indicate less mixing and dispersion of pollutants in the summer to fall season. Similarly, the pattern of precipitation is one of a relatively rainy season in the winter and spring and very little precipitation in the summer and fall. In 1974, May, August, and September each had less than 0.01 inches of precipitation. These two meteorological factors result in TSP levels 50 percent higher in the highest months than in the winter.

## URBAN ACTIVITY

Two studies by the BAAPCD were broadly included under this discussion. The first related to a comparison of TSP levels measured at two different heights in San Francisco. The results of this analysis indicated that the measurements taken at the lower site (approximately 40 feet back from the road) were almost 12 percent higher than those sampled on the roof (100 feet from the road).

The other BAAPCD study consisted of analyses of 600 cellulose hi-vol filters sampled at 8 stations over a period of 21 months. The analyses were conducted to determine the silicate and chloride contribution to the TSP levels. The results illustrated that ocean spray was less of a factor at the inland sites than at sites close to the ocean such as San Francisco but that the contribution from silicates increased with distance from the ocean. As much as 42 percent of the levels measured were found to be chlorides and silicates. The highest mean sodium chloride measurement of 7 $\mu g/m^3$ in San Francisco is indicative of the TSP concentrations entering the region from the Pacific Ocean.

## CONCLUSIONS

The results of this study signify that the lack of a major particulate problem in the Bay Area is due to the generally low level of emissions into clean air off the ocean. Controls on these emissions, while not stringent, are apparently adequate for the time. Further control may be needed in the future especially for major fuel burners because of natural gas shortages. In addition, it may be necessary to apply specific controls on sources of fugitive dust in the summer to fall months when precipitation and ventilation acts to increase particulate levels.

## REVIEWERS' COMMENTS

The draft report for each city was submitted to interested EPA, state, and local officials for comment on the contents and findings. Comments of an editorial nature were reconciled; comments of a substantive nature which reflect differences of opinion were compiled and are presented below.

> A more recent inventory for the BAAPCD after this document was written. Particularly regarding Figure 12, page 23, the reader is referred to the BAAPCD for more recent projections.
>
> The concentrations in Table 1, page 12 differ slightly from California Air Resource Board values because of differences in rounding.
>
> On page 25, the point is made that trends in coal use account for much of the reduction in air quality levels since measurements begin. Reviewers question that this is the only factor.

## SECTION I

## STATEMENT OF THE PROBLEM

### CHARACTERISTICS OF THE REGION

The San Francisco Bay Area Intrastate Air Quality Control Region (AQCR) encompasses the counties of Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, and Sonoma. It is a midlattitude region extending along the Pacific Ocean with a length approximately twice its width. For the purpose of this study, major attention was directed at that portion of the region under the authority of the Bay Area Air Pollution Control District (shown as shaded in Figure 1). The total land area within its jurisdiction is over 5600 square miles with almost 500 square miles of water surface area. The center of the AQCR is the San Francisco Bay, a large shallow basin ringed by hills as high as 2000 feet which tapers into a series of sheltered valleys. This topography gives the area great potential for trapping and accumulating air pollutants.

#### Economic Structure

Most of the 4.7 million people in the Bay Air Air Pollution Control District (BAAPCD) reside along the San Francisco Bay in two Standard Metropolitan Statistical Areas (SMSA's) - San Francisco-Oakland and San Jose. The San Francisco-Oakland SMSA is the sixth largest SMSA in the country with a population of over 3 million and the San Jose SMSA, ranking 31st in the nation, has over 1 million people. In addition the BAABCD contains two smaller SMSA's - the Vallejo-Fairfield-Napa SMSA and the Santa Rosa SMSA. The percent growth in population (1960-1970) for these SMSA's has ranged

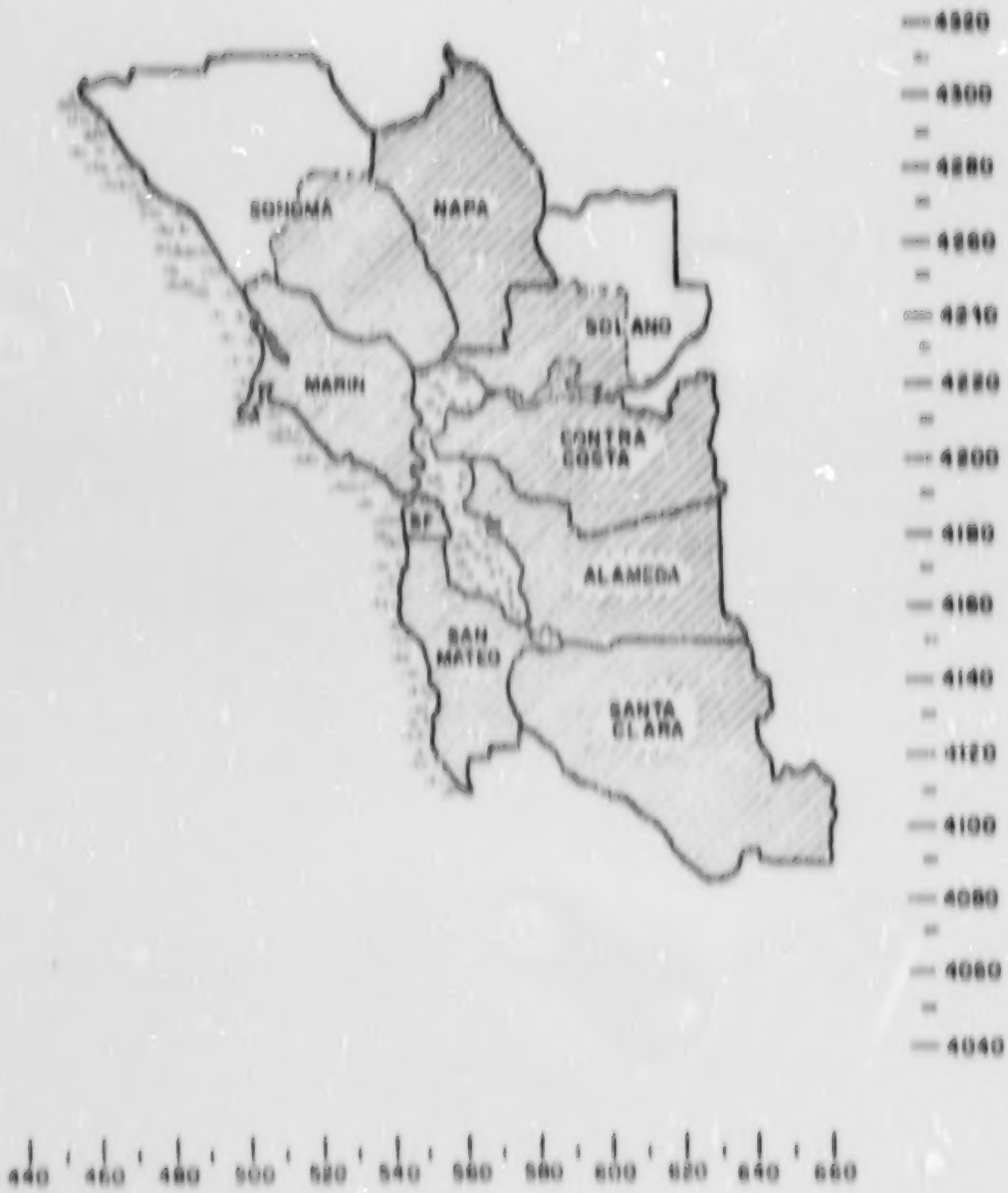


Figure 1. San Francisco Bay Area Air Quality Control Region and the Bay Area Air Pollution Control District (shaded area)

from 17.4 percent for the San Francisco-Oakland SMSA to almost 66 percent for the San Jose SMSA.

The economic structure of the AQCR is dominated by employment in relatively clean industry. Over 22 percent of those employed are in services, 27 percent are in wholesale and retail, and another 20 percent are in finance, insurance, real estate, transportation, and other public utilities. In the category of manufacturing (24 percent of the employment), the largest employers are the food processing industry and the electrical equipment industry with 15 and 20 percent of the manufacturing employment respectively. Figure 2 provides a graphical representation of the manufacturing employment mix in the AQCR by 2-digit Standard Industrial Classification (SIC) code. While the District's employment is primarily not in major industries, the largest contributions to the total particulate emissions are made by those classified Chemical, Food, and Other Industry (20 percent) and Metallurgical and Mineral Industry (21 percent). Another 31 percent is contributed by various modes of transportation.[1]

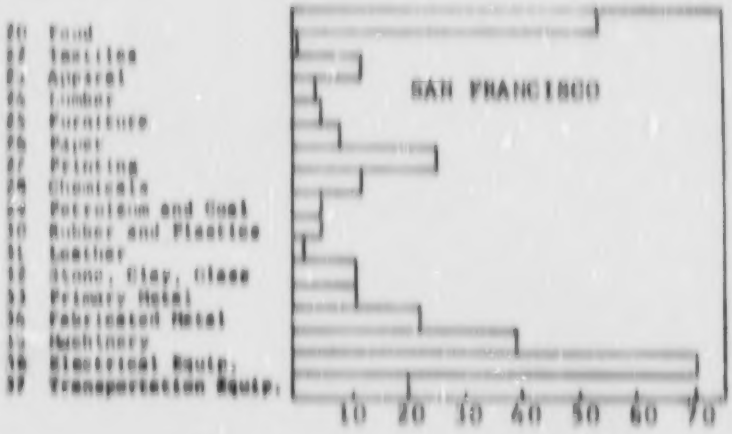


Figure 2. Manufacturing employment in the San Francisco Bay Area AQCR

## Climate

The climate in the AQCR is predominantly a midlatitude, west coast, maritime-type, with dry, cool summers and moderately wet winters. However, there are wide contrasts in climate and meteorology within short distances of the San Francisco Bay area. Even within the City of San Francisco there are differences in climate, the most obvious being the greater frequency and duration of fogs or low stratus cloudiness along the western, Pacific coastal side of the city. These sea fogs constitutes one of the more striking characteristics of San Francisco's climate. In the summertime, the temperature of the Pacific Ocean is unusually low near the coast and atmospheric pressure relatively high, while the interior of California is characterized by the opposite in both elements. This tends strongly to intensify the landward movement of air and to make the prevailing westerly winds brisk and persistent, especially during the period from May to August. The fog or low-lying stratus cloudiness off the coast is carried inland by strong westerly winds during the afternoon or night and evaporated during the subsequent forenoon. Notwithstanding the occurrence of these stratus clouds, the sun shines on an average of 66 percent of the daylight hours in downtown San Francisco.

As a result of the steady sweep of fresh air from the Pacific, there are few extremes of heat or cold. During the entire period of temperature records in San Francisco, temperatures have risen to 90° or higher on an average of but once a year and dropped below freezing less than once a year. As a rule, abnormally warm or cool periods last but a few days. The diurnal land- and sea-breeze characteristic of many coastal regions does not prevail here. Winds from the land are extremely rare, and it is during these infrequent and brief interludes in the normal west wind of the warm months that the occasional hot days occur. The summer weather is dominated by a cool sea breeze resulting in an average summer wind speed of nearly 15 mph. Winds are light in the early morning but normally reach 20 to 25 mph in the afternoon.

Pronounced wet and dry seasons are another characteristic of this climate. On the average, 84 percent of the total annual precipitation falls during the 5-month period, November to March. Measurable amounts of precipitation fall on less than 70 days a year. The normal level of precipitation is about 20 inches of rain each year; however, in 1974 less than 16 inches fell. The months of May, August, and September received only trace amounts of precipitation in 1974.

The nearby communities in Marin County, lying just to the north across the Golden Gate and sheltered from the prevailing ocean winds by the fairly high peaks and ridges of the Coast Range, enjoy generally warmer and sunnier weather than San Francisco. Their climate is further modified by proximity to San Francisco and San Pablo Bays to the eastward. In general, temperatures increase from south to north, with correspondingly greater daily ranges, and also increase slightly with distance from the bays. Daily maximum temperatures for July average 16° to 18° warmer only 20 miles north of San Francisco. As in San Francisco, there are well defined wet and dry seasons, but rainfall amounts are strongly influenced by the topography of the Coast Range. Annual average rainfall varies from 26 inches to 49 inches within this area.

Southward along the peninsula east of the Coastal Mountains summers are warmer and less windy, due to the diminishing influence of the sea breeze. However, areas adjacent to a pass or saddle in the Coastal Mountains are usually cooler and more windy than areas protected by higher ridges. Thus, the highly populated area along the Bay down toward San Jose enjoys a modified Mediterranean type climate. The winters are much the same as for San Francisco, but protected spots are 5° to 10° colder on clear, calm nights. The summers are sunny and warm.

The coastside of the peninsula area, containing relatively sparse and small agricultural communities, has a more exclusive marine-type climate. In summer, due to the greater persistence of fog and low overcast, the daily

temperature range is less, with daytime temperatures lower than those experienced east of the Coastal Mountains. The winter months are generally free of fog and during this period, due to the more direct, moderating influence of the Pacific Ocean, nighttime temperatures do not drop as low as those on the east side. The additional orographic lifting provided by the Coastal Mountains produces somewhat heavier rainfall amounts along the coastal strip and adjacent mountain area than on the east side of the peninsula.

AIR QUALITY PLANNING

Except for parts of Solano and Sonoma counties, the program of air pollution control in the San Francisco Bay Area AQCR is principally conducted by the Bay Area Air Pollution Control District for the policing of non-vehicular sources of air pollution within the Bay Area. The BAAPCD was created by the California Legislature in 1955 - the first regional agency dealing with air pollution to be formed in California. Although the main automotive control program is administered by the State of California's Air Resources Board in Sacramento, the BAAPCD was recently authorized to cite smoking vehicles.

For implementation planning, the San Francisco AQCR was designated as a Priority I region (exceeding the primary National Ambient Air Quality Standards) for carbon monoxide and photochemical oxidants, a Priority II region (exceeding the secondary NAAQS) for total suspended particulates and sulfur dioxide, and a Priority III region for $NO_2$. The Implementation Plan for Achieving Air Quality Standards in the San Francisco Bay Area Air Basin was completed by the BAAPCD and submitted to the Air Resources Board in October 1971; it was subsequently submitted as part of the state implementation plan (SIP) to EPA in February 1972. Under this plan the BAAPCD predicted that the particulate standards (both Federal and State) would be met by 1973 as a result of the existing regulations which had been recently tightened. While the standards for total suspended particulates (TSP) are expected to be attained in the San Francisco AQCR, the

area has been designated as a maintenance area for particulate matter as well as sulfur dioxide and photochemical oxidants.

## AIR QUALITY SUMMARY

Trends in ambient TSP concentration have been fairly constantly downward over the years. Since 1957, several National Air Sampling Network (NASN) monitors have been operating in the region and reporting TSP levels. At the San Francisco NASN site, there was a 30 percent decrease from 73 $\mu g/m^3$ in 1957 to 51 $\mu g/m^3$ in 1974; at the Oakland site, levels, dropped 40 percent from 87 $\mu g/m^3$ in 1958 to 52 $\mu g/m^3$ in 1974; in Berkeley a 64 percent decline occured between 1959 (88 $\mu g/m^3$) and 1974 (30 $\mu g/m^3$). This trend data is plotted in Figure 3 along with the data for the NASN site that operated in San Jose during this time.

At the end of 1968, the BAAPCD started to operate eight stations in the District. On the whole, the levels recorded at these monitors have shown only a small decline since 1969. At the Pittsburg site the TSP levels have decreased 28 percent over this time but at the Livermore monitor the levels were 13 percent higher in 1974 than in 1969. At the San Francisco site no real change was noted. The trends at these eight stations are plotted in Figure 4.

The BAAPCD operated 26 monitoring stations during all or part of 1974. At 14 of these stations, total suspended particulates were measured throughout the year and two other stations, one in the eastern portion of San Francisco County and the other in Gilroy, started sampling in July of that year. Another three monitors were operated as part of the National Air Sampling Network (NASN). These stations are distributed around the District, as shown in Figure 5, with many of them located in the basin of the San Francisco Bay to monitor the levels near the more heavily populated areas.

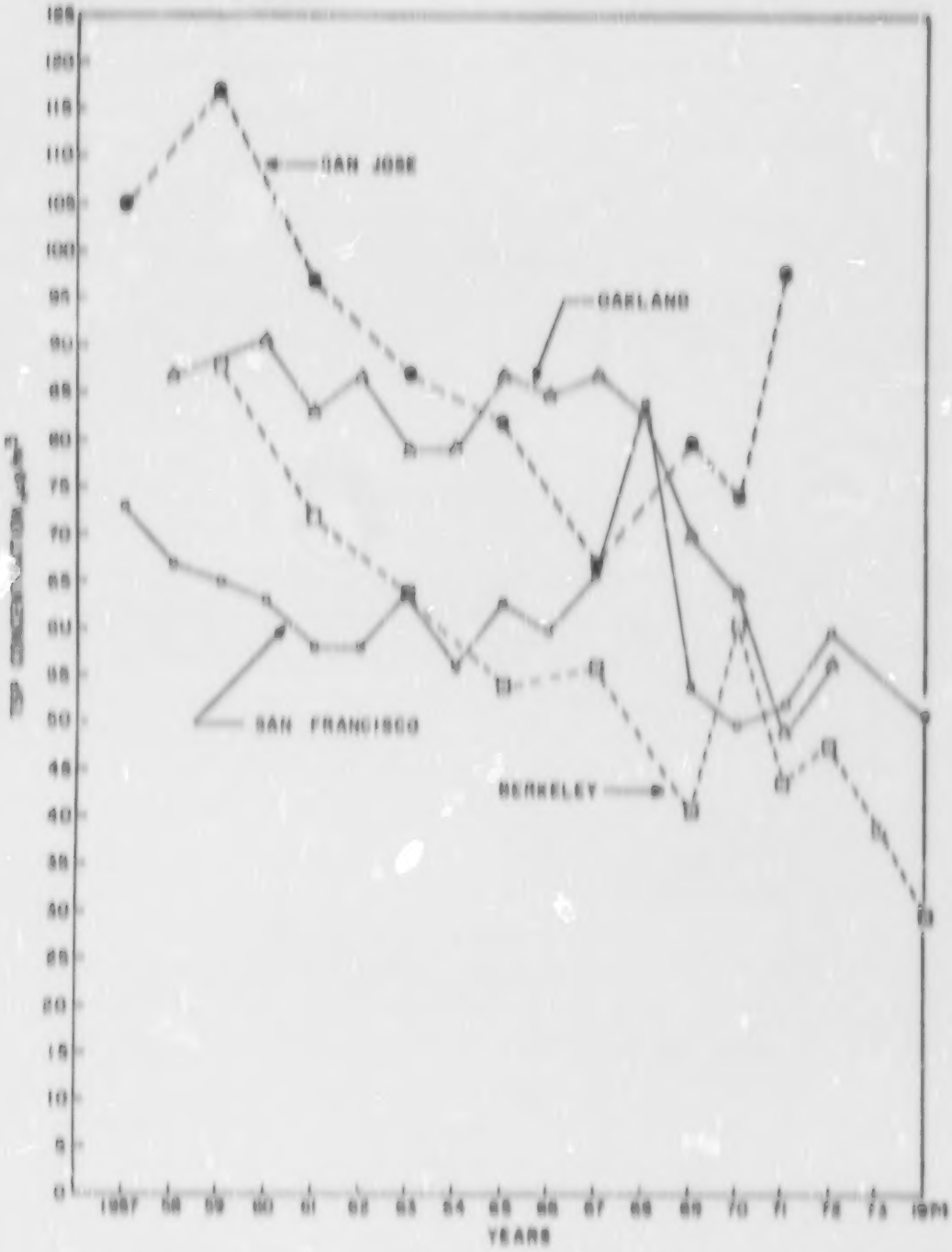


Figure 3. TSP levels at NASN sites in the San Francisco Bay Area AQCR, 1957-1974

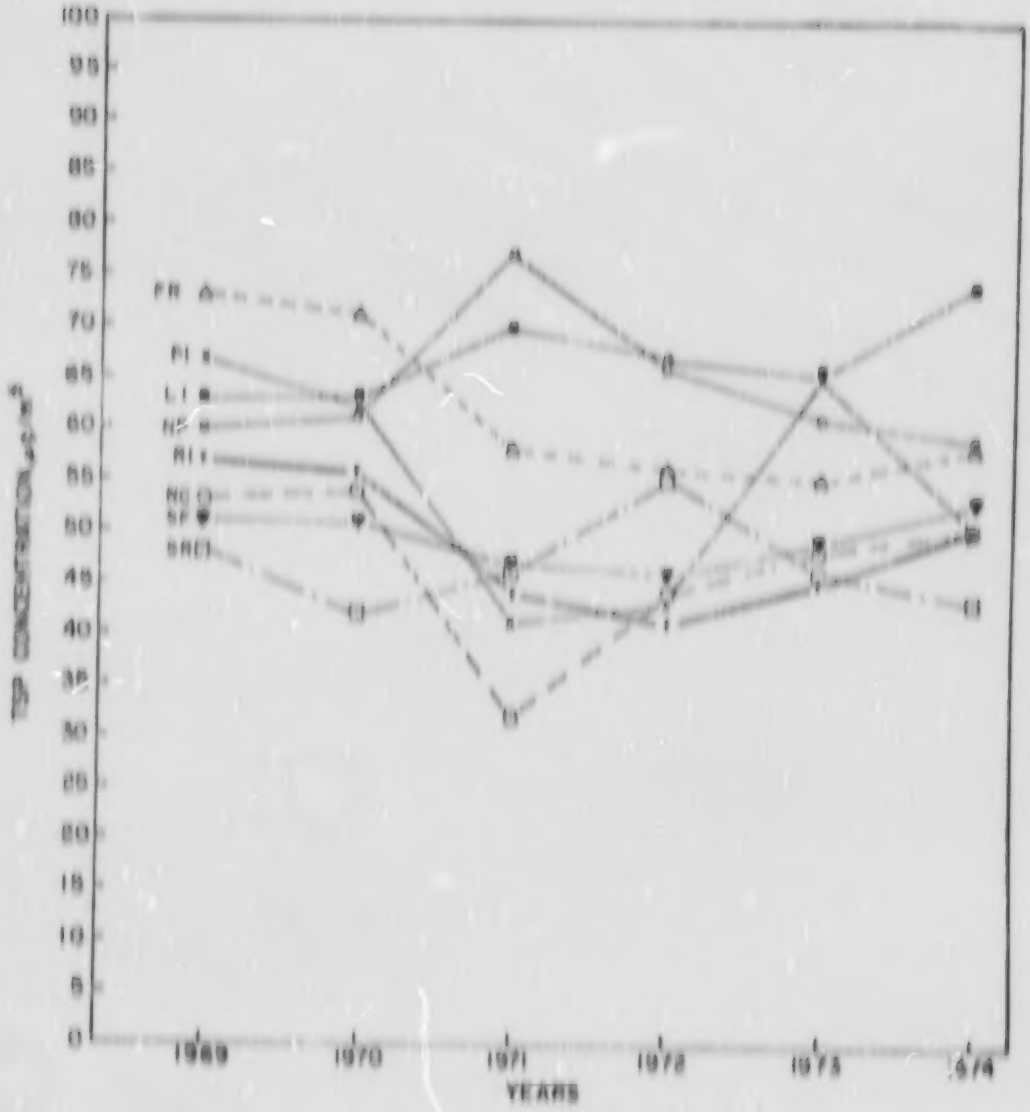


Figure 4. TSP levels in the Bay Area Air Pollution Control District, 1969-1974

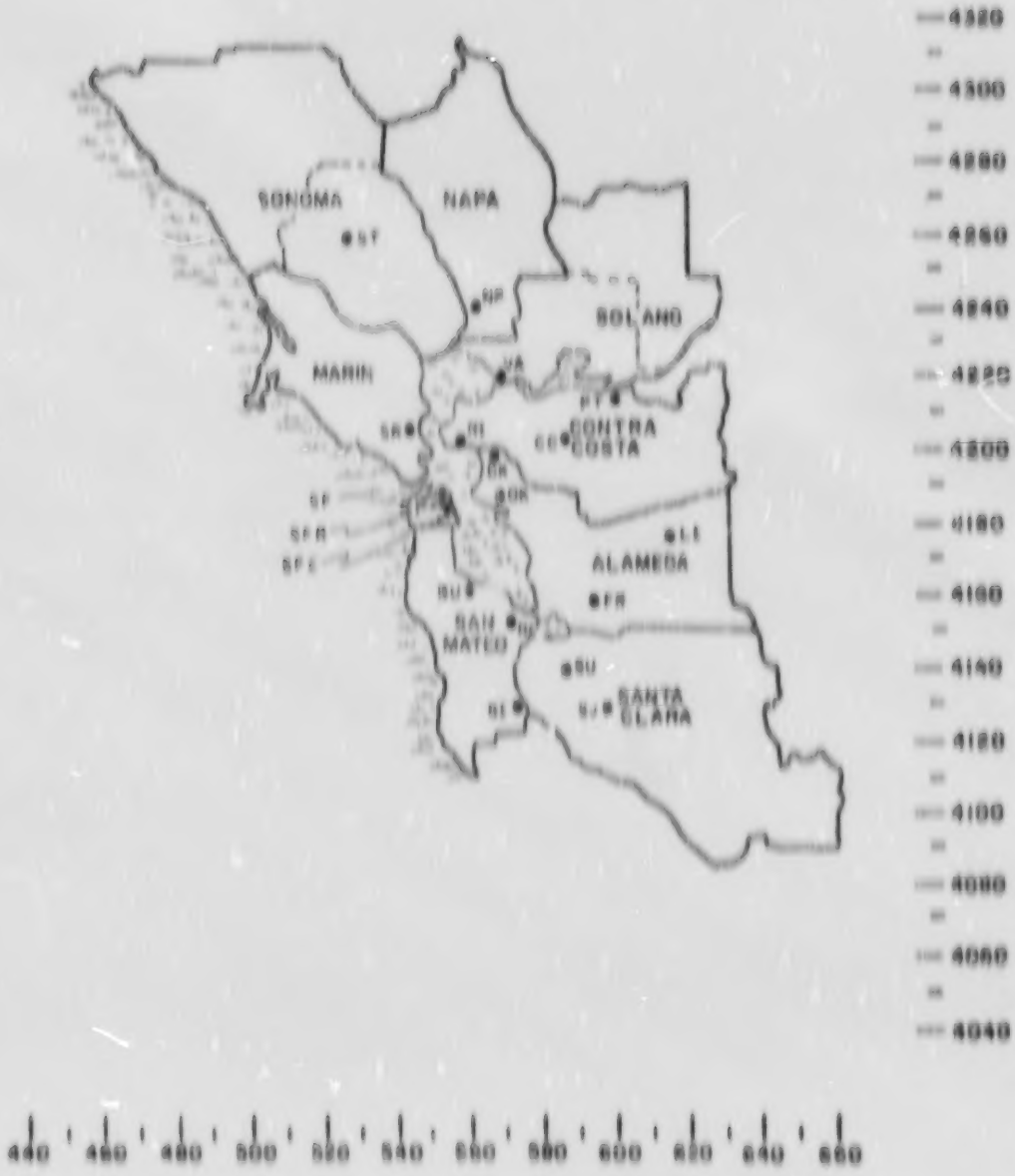


Figure 5. - Location of particulate monitoring sites in the Bay Area Air Pollution Control District

Specific information on each of the stations is given in Table 1 and the 1974 geometric means at each of these stations is given in Figure 6 to provide an idea of the spatial distribution of total suspended particulate (TSP) level. As may be seen from this table and figure, the primary annual standard for particulates (75 $\mu g/m^3$) was met at all stations in 1974 with only one station (Livermore) close to that value. As discussed later, the Livermore monitor is expected to be highly impacted by fugitive dust. Only one other station (Vallejo) was found to be violating the secondary annual standard (60 $\mu g/m^3$) in 1974 and one station (Napa) was exactly meeting the standard. Violations of the primary 24-hour standard (260 $\mu g/m^3$) were practically nonexistent and the secondary 24-hour standard (150 $\mu g/m^3$) was exceeded at only a few stations on a few occasions. However, the state's air quality standard of 100 $\mu g/m^3$ for 24 hours was exceeded at all stations at least once with over 28 percent of the observations at Livermore violating this standard.

The seasonal pattern of TSP concentrations in 1974 was one of higher levels from late spring through fall and lower levels during the winter months. This basic pattern was generally consistent throughout the District regardless of the neighborhood as may be seen from plots of the monthly geometric means at several of the monitors with commercial influence (Figure 7) and all of the monitors with industrial and residential influences (Figures 8 and 9 respectively). On a District-wide average, the peak values experienced in September 1974 were about 50 percent higher than those in the winter months. This pattern is felt to be primarily a result of the meteorology of the area as discussed in Section II.

Table 1. CHARACTERISTICS OF MONITORING SITES IN THE BAAPCB - 1974

| Map code | City | Address | Site characteristics | Height above ground, feet | 1974 TSP geometric mean | Number of observations | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Exceeding primary standard | Exceeding secondary standard | Total |
| 1[illegible] | San Francisco (BAOT) | 101 Green St. | Center city - commercial | 32 | 51 | | | 26 |
| 5F | San Francisco | 939 Ellis St. | Center city - commercial | 15 | 53 | | 1 | 117 |
| 5B | San Rafael | 542 4th St. | Center city - commercial | 23 | 43 | | | 121 |
| 8C | Sunnyvale | 251 S. Murphy Ave. | Center city - commercial | 33 | 41 | | | 122 |
| 9C | San Clemente | 1329 San Clemente Ave. | Center city - commercial | 34 | 36 | | | 120 |
| 5T | Santa Rosa | 427 Humboldt St. | Center city - commercial | 18 | 38 | | | 115 |
| 9F | Napa | 2592 Jefferson Ave. | Center city - commercial | 14 | 45 | 1 | 3 | 120 |
| 9A | Vallejo | 400 Tuolumne St. | Center city - commercial | 28 | 62 | 1 | 4 | 120 |
| 4C | Gilroy | 7671 Monterey St. | Center city - commercial | 13 | 54 | | 1 | 40 |
| 6K | Oakland (CHSO) | 499 5th St. | Center city - industrial | 42 | 52 | | | 27 |
| 5F2 | San Francisco | 900 22nd St. | Center city - industrial | 30 | 56 | | 2 | 10 |
| 2K | Berkeley (CHSO) | Calif. State Health Dept. | Center city - residential | 90 | 38 | | | 26 |
| 5U | San Jose | 1355 N. 4th St. | Center city - residential | 15 | 59 | | | 116 |
| 8L | Richmond | 1344 11th St. | Suburban - commercial | 17 | 50 | | 1 | 122 |
| 1I | Livermore | 1500 Railroad Ave. | Suburban - commercial | 19 | 74 | | 6 | 118 |
| 8C | Redwood City | 897 Barron Ave. | Suburban - commercial | 11 | 53 | | | 50 |
| 8T | Pittsburg | 383 W. 3rd St. | Suburban - industrial | 30 | 50 | | 2 | 120 |
| 6C | Concord | 996 Treat Blvd. | Suburban - residential | 3 | 47 | | 1 | 121 |
| 9B | Fremont | 40733 Chapel Way. | Suburban - residential | 16 | 58 | 1 | 3 | 121 |
| Total | | | | | | 3 | 24 | 1828 |

Figure 6. TSP annual geometric means at monitors in the Bay Area Air Pollution Control District

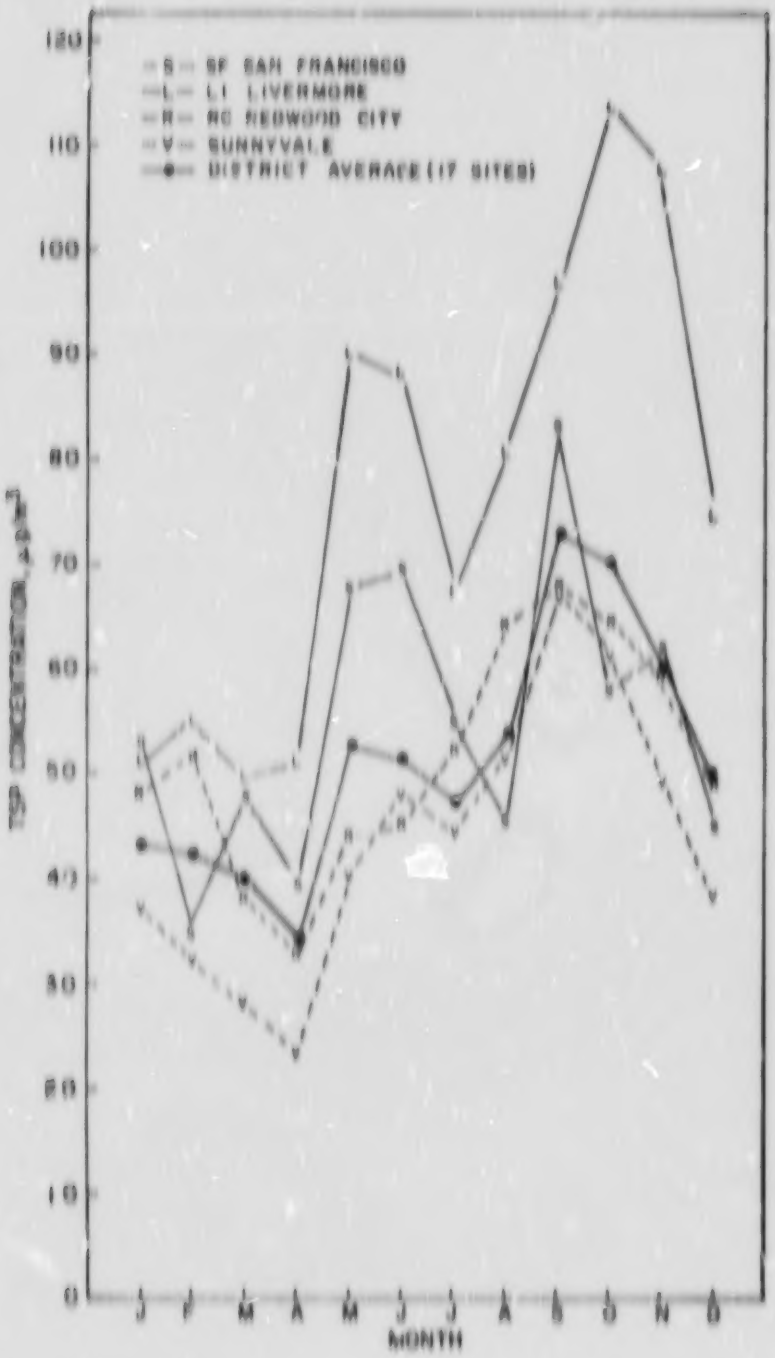


Figure 7. Monthly geometric means at several monitors in commercial neighborhoods in the BAAPCD-1974

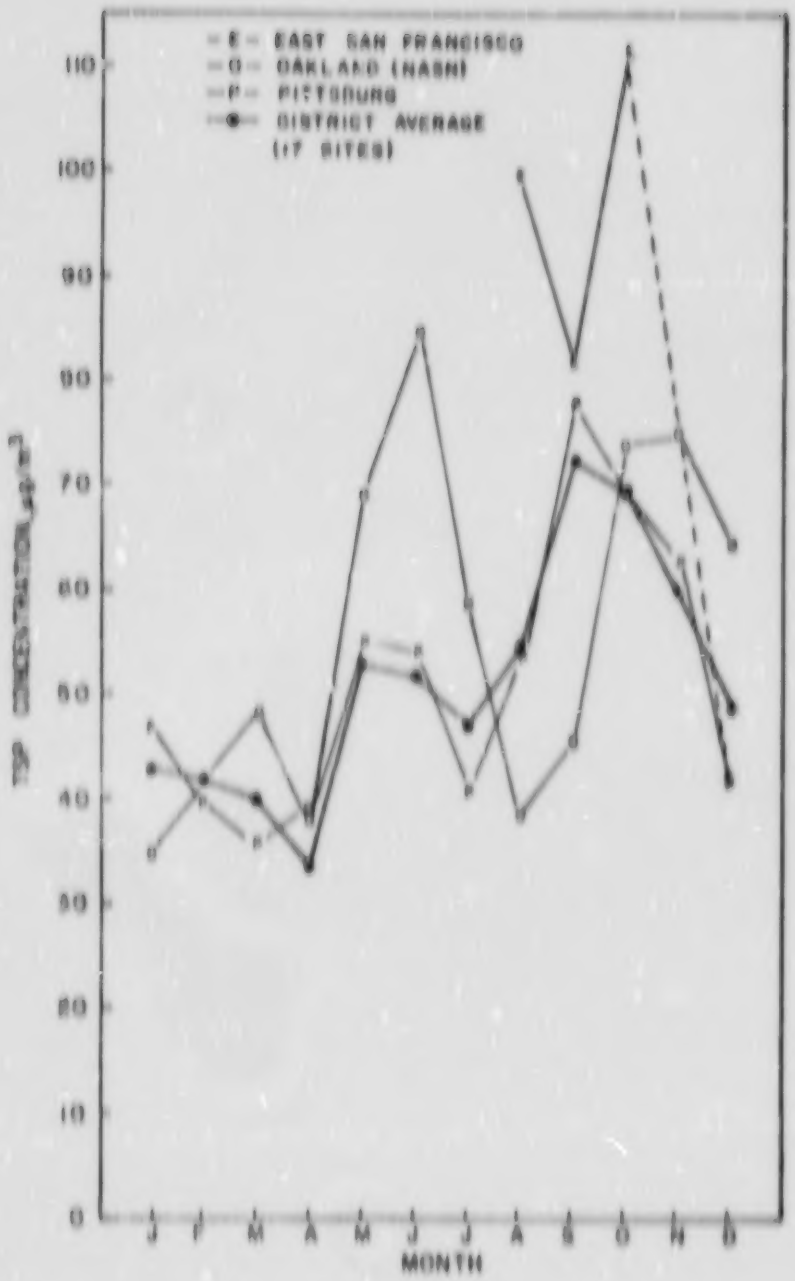


Figure 8. Monthly geometric means at monitors in industrial neighborhoods in the BAAPCD-1974

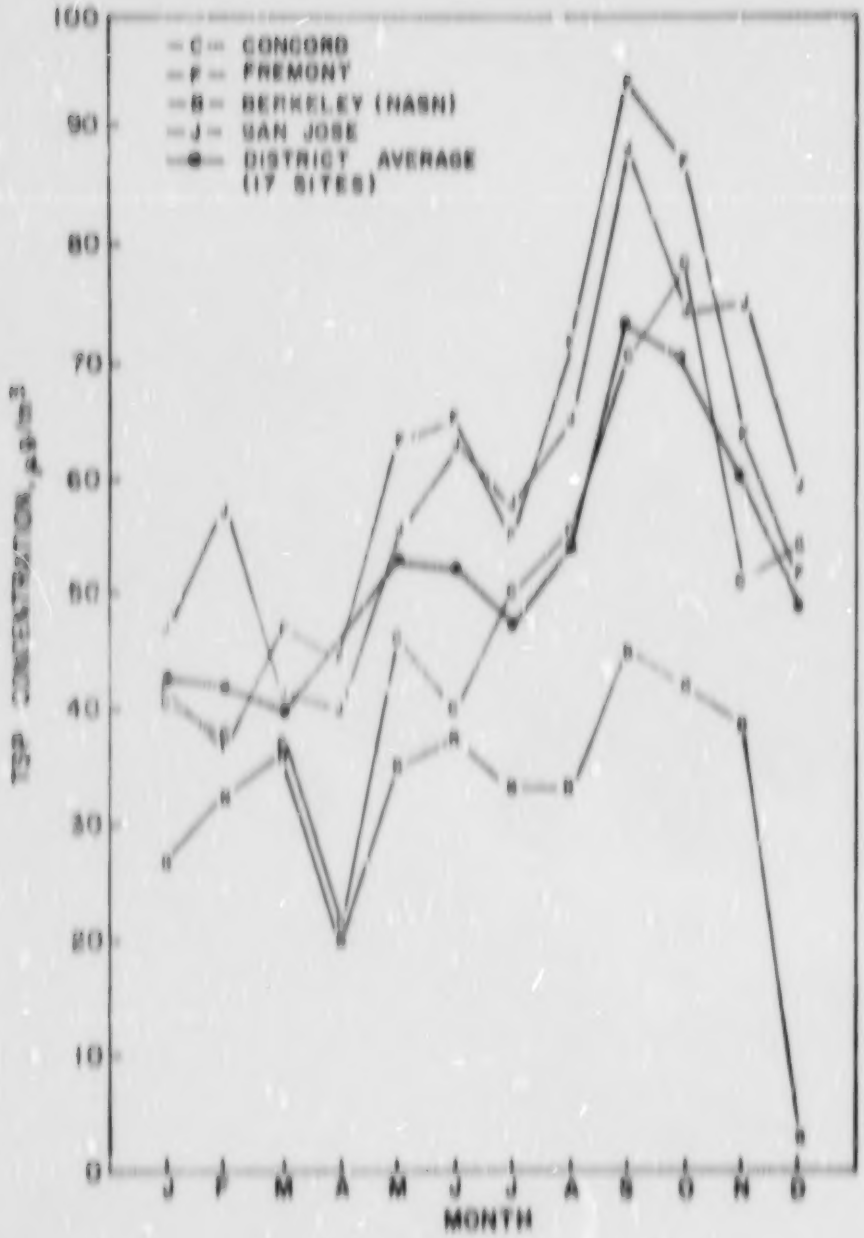


Figure 9. Monthly geometric means at monitors in residential neighborhoods in the BAAPCD-1974

## REFERENCES

1. Source Inventory of Air Pollutant Emissions in the San Francisco Bay Area - 1973. Bay Area Air Pollution Control District, San Francisco, California.

## SECTION II

## ANALYSES

This section presents the individual analyses that were performed on the data gathered for the study of the particulate problem in the San Francisco area. It attempts to correlate various factors which are known to influence air quality with the measured ambient TSP concentrations. These factors include those that most often come under the jurisdiction of the air pollution control agency - emissions, regulations, and monitor siting - and other factors that are not usually or cannot be controlled - urban activity, meteorology, etc.

### EMISSIONS

#### Sources and Distributions

The Bay Area Pollution Control District is a lightly industrialized area with many of the major point sources located away from the centers of population. The largest point source of particulates, according to the BAAPCD 1973 emission inventory,[1] had a daily emission rate of 3.5 tons and there were 26 point sources with emission rates greater than or equal to 0.2 tons per day. Figure 10 locates these point sources and provides an idea of the relative size of each source. As may be seen from this figure, the greatest number of major sources are distributed around Contra Costa County.

While the locations of these sources indicate where major industrial activity is underway, they do not necessarily represent where the

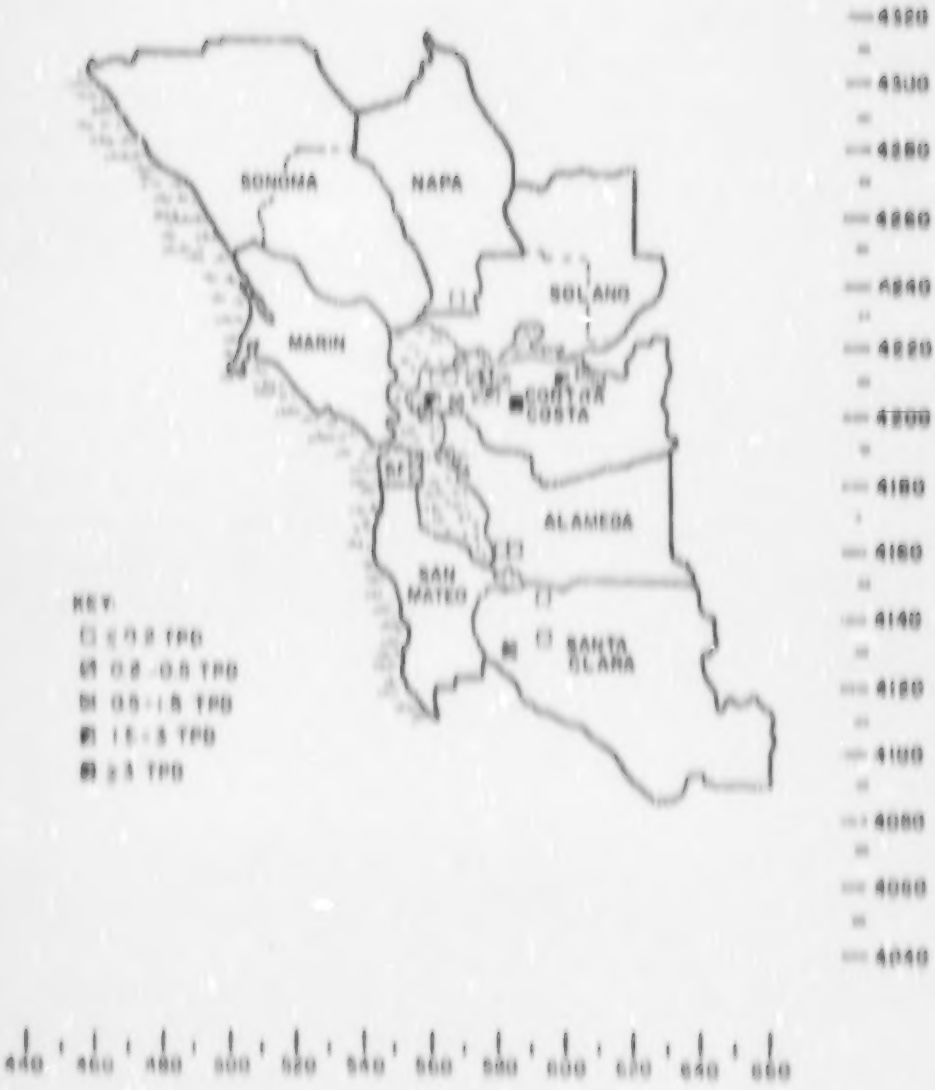


Figure 10. Location of major point sources in the BAAPCD

highest emission densities are occurring since the total emissions from these sources reflect less than 18 percent of the daily emissions of 160 tons in the BAAPCD. Instead, it is expected that the greatest density of emissions is to be along the Bay from San Francisco and Berkeley down to San Jose. For example, in San Francisco County with 12 percent of the total emissions in the District, the emission density would be over 850 lbs/day/sq mile of land area; whereas in Contra Costa County, with 19 percent of the District's emissions, an average emission density for the county would be around 80 lbs/day/sq mile. Table 2 presents the emissions in each county in the District, breaking out transportation sources from those sources that come under the control of BAAPCD.

To provide a better understanding of the sources contributing to the total particulate emissions in the District, a breakdown of the basic source types in the BAAPCD is given in Table 3 for both the BAAPCD controlled sources and transportation sources. The data in this table indicates that almost 60 percent of the emissions from sources under the jurisdiction of the BAAPCD come from two industry categories - metallurgical and mineral industry; chemical, food, and other industry. The total contribution from industry is approximately half of the emissions in the District.

Trends

In its compilation of an emission inventory for 1973, the BAAPCD also developed an emission inventory for each month of the year. Those monthly inventories indicate that there is very little seasonal pattern in the total particulate emissions for the District. While the total emissions vary less than 5 percent over the year, there are definite seasonal patterns in the emissions from fuel combustion and transportation; however, these patterns are opposite to each other and therefore do not result in a major pattern for the total emissions. The

Table 2. PARTICULATE EMISSIONS IN EACH COUNTY IN THE BAAPCD - 1973[1]

| County | Sources | Average annual emissions, tons/day | Percent contribution in county | Percent of district | County wide emission density, lbs/day/sq. mi.[a] |
|---|---|---|---|---|---|
| Alameda | BAAPCD Controlled | 18 | 62 | | |
| | Transportation | 11 | 38 | | |
| | Total | 29 | | 18 | 79 |
| Contra Costa | BAAPCD Controlled | 28 | 88 | | |
| | Transportation | 4 | 12 | | |
| | Total | 31 | | 19 | 83 |
| Marin | BAAPCD Controlled | 4 | 57 | | |
| | Transportation | 3 | 43 | | |
| | Total | 7 | | 4 | 25 |
| Napa | BAAPCD Controlled | 6 | 90 | | |
| | Transportation | 1 | 10 | | |
| | Total | 6 | | 4 | 18 |
| San Francisco | BAAPCD Controlled | 16 | 82 | | |
| | Transportation | 3 | 18 | | |
| | Total | 20 | | 12 | 833 |
| San Mateo | BAAPCD Controlled | 12 | 55 | | |
| | Transportation | 9 | 45 | | |
| | Total | 22 | | 13 | 93 |
| Santa Clara | BAAPCD Controlled | 15 | 54 | | |
| | Transportation | 13 | 46 | | |
| | Total | 28 | | 16 | 39 |
| Solano | BAAPCD Controlled | 7 | 64 | | |
| | Transportation | 4 | 36 | | |
| | Total | 11 | | 7 | 61 |
| Sonoma | BAAPCD Controlled | 8 | 87 | | |
| | Transportation | 1 | 13 | | |
| | Total | 9 | | 6 | 20 |
| Total | BAAPCD Controlled | 110 | 69 | | |
| | Transportation | 49 | 31 | | |
| | Total | 160 | | 100 | 37 |

[a]Based on total land area in each county; actual emission density at any point is expected to vary widely from this value.

Table 3. PARTICULATE EMISSIONS FROM DIFFERENT SOURCE TYPES IN THE BAAPCD - 1973[1]

| | Emissions (TPD) | Percent of total |
|---|---|---|
| Petroleum refining | | |
| Boilers and Heaters | 3.9 | 2.4 |
| F.C.C., Cokers, CO Boilers | 3.5 | 3.4 |
| Other | 0.8 | 0.5 |
| Chemical, food, & other ind. | | |
| Asphalt | 0.1 | .. |
| Sulfur | 2.5 | 1.6 |
| Sulfuric Acid | 0.4 | 0.2 |
| Pulp and Paper | 0.6 | 0.4 |
| Other | 28 | 17 |
| Organic solvents | | |
| Coating Operations | 5.6 | 3.5 |
| Rubber, Plastic Product Mfg | 0.7 | 0.5 |
| Metallurgical & mineral ind. | 34 | 21 |
| Combustion of fuels | | |
| Domestic | 3.5 | 2.2 |
| Commercial | 1.6 | 1.0 |
| Industrial | 5.0 | 2.5 |
| Utilities - Power Plants | 5.0 | 3.1 |
| Burning of materials | | |
| Incineration | 1.6 | 1.0 |
| Agricultural Open Burning | 2.1 | 1.3 |
| Accidental Fires | 6.0 | 3.7 |
| Off-highway mobile sources | | |
| Agricultural Tractors | 0.3 | 0.2 |
| Construction Equipment | 0.9 | 0.5 |
| Ships | 1.3 | 0.8 |
| Locomotives | 0.6 | 0.4 |
| Other Engines | 2.1 | 1.3 |
| Total (BAAPCD jurisdiction) | 110 | 68 |
| Aircraft | | |
| Air Carriers | 6.1 | 3.7 |
| General Aviation | 0.8 | 0.5 |
| Military | 4.3 | 2.7 |
| Motor vehicles | | |
| Cars and Light Duty Trucks | 31 | 20 |
| Heavy Duty Trucks - Gasoline | 1.7 | 1.1 |
| - Diesel | 3.7 | 2.3 |
| Buses | 0.3 | 0.3 |
| Motorcycles - 2 Stroke | 0.2 | 0.1 |
| - 4 Stroke | - | - |
| Grand total | 160 | 100 |

increase in emissions from transportation are a result of the increased motor vehicle activity in the summer. The emissions from fuel combustion are less during the summer due to reduced space heating demands and also in 1973 a natural gas shortage forced many industrial users to switch to fuel oil during the cold season, thereby increasing further the emissions of particulates at this time. The monthly levels of emissions from all transportation sources, fuel combustion, burning of materials, and industry, as well as the total monthly emissions (divided by 2 to fit on the graph) are plotted in Figure 11.

Although the annual emissions appear to be fairly constant over the year, the change in emissions from year to year has been considerable. Figure 12, presented below, is a graphical representation of how the emissions have changed over time. (The dotted portion of the curve is a projection into the future based upon a continuing shortage of natural gas and increased use of fuel oil.) This figure indicates that total particulate emissions have dropped almost 40 percent from their highest point in the late 1950's.

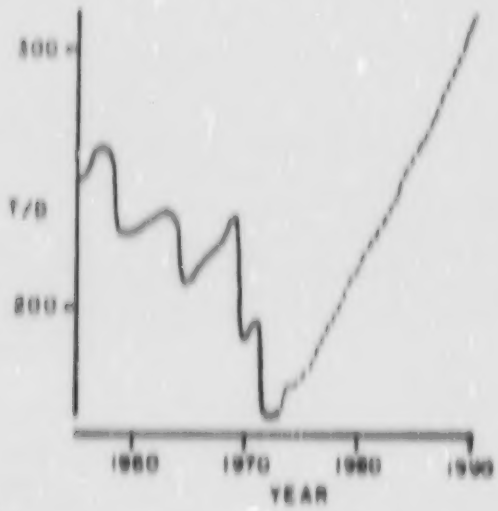


Figure 12. Long-term trends in total annual particulate emissions in the BAAPCD[1]

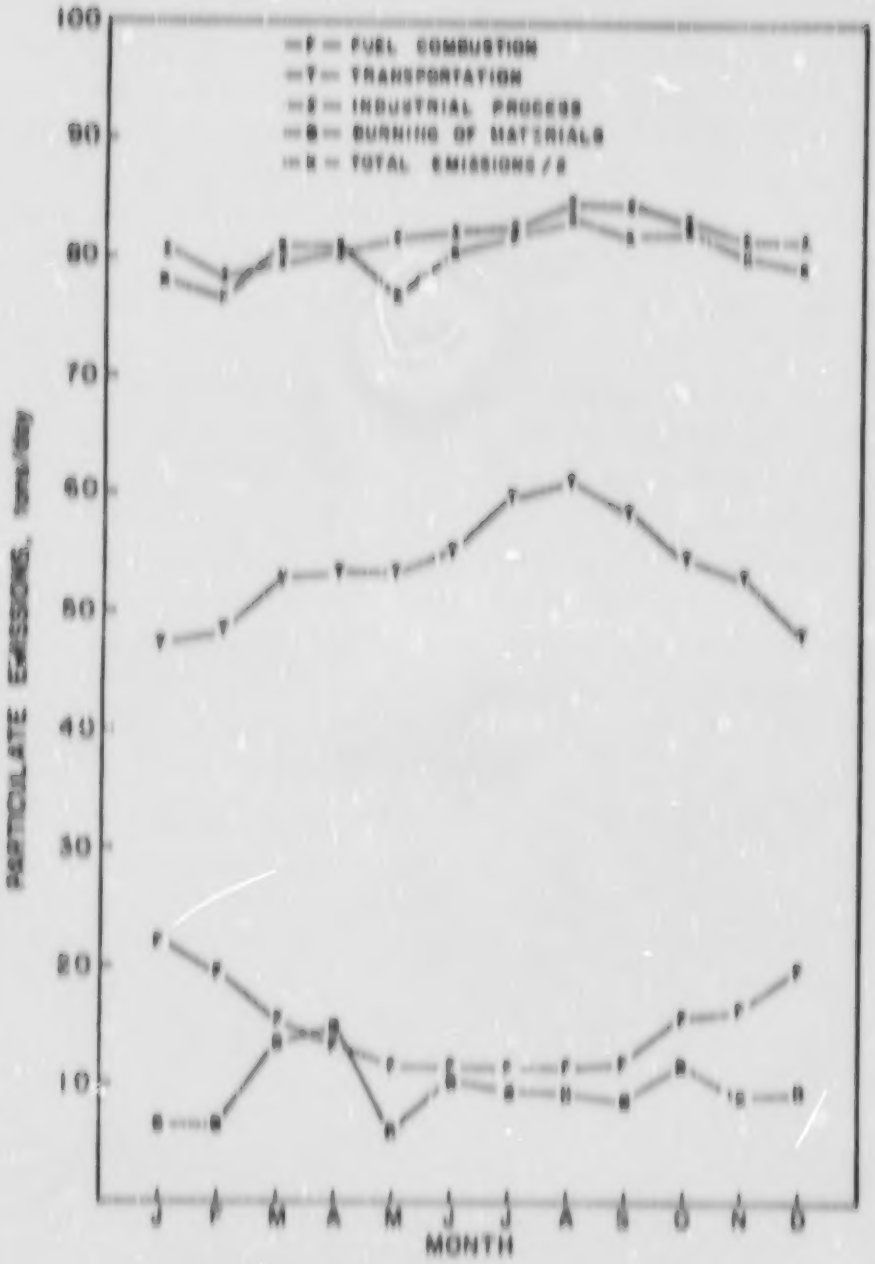


Figure 11. Monthly emissions in the BAAPCD by source category - 1973[1]

More detailed data was available on the emissions from different source categories since 1969. This data, broken down for the same source categories as given in Figure 11, is plotted in Figure 13. (The 1974 emissions were projected from the 1973 base year by the BAAPCD and do not represent 1974 base year calculations.) It is apparent from this figure that the major decreases in emissions have occurred through control of industrial sources and burning of materials. The emissions from transportation sources have increased concurrently with the increased vehicle miles travelled. The emissions from fuel combustion increased in 1973 due to the natural gas shortage, with further shortages and increased fuel oil usage reflected in the projected 1974 emission rate. This decrease in Districtwide emissions is comparable to the trends in ambient air quality presented in Figure 4.

The projected increase in total emissions due to the natural gas shortage raises questions regarding what impact this change in fuel combustion would have on the ambient air quality. In earlier years, the use of coal and oil was more prevalent in the area than currently. Table 4 provides a breakdown of the energy usage between 1950 and 1973 for the residential sector and electric utilities in San Francisco County. Table 5 provides similar data for the residential sector and industry in the San Francisco - Oakland SMSA. The data in these tables indicate that electricity and gas are the predominant energy sources for residences (over 98 percent of all dwelling units) and gas is primarily used by industry and utilities. With the rise in dwelling units, there has been a substantial decrease in those units using coal and, in the SMSA, oil. The rise in residential oil consumption in San Francisco County between 1960 and 1970 is almost exactly equal to the drop in the number of dwelling units using coal.

This change in energy usage appears to have had a significant impact on the seasonal pattern of air quality. A report on suspended particulate matter between 1957 and 1967 prepared by the BAAPCD tabulated

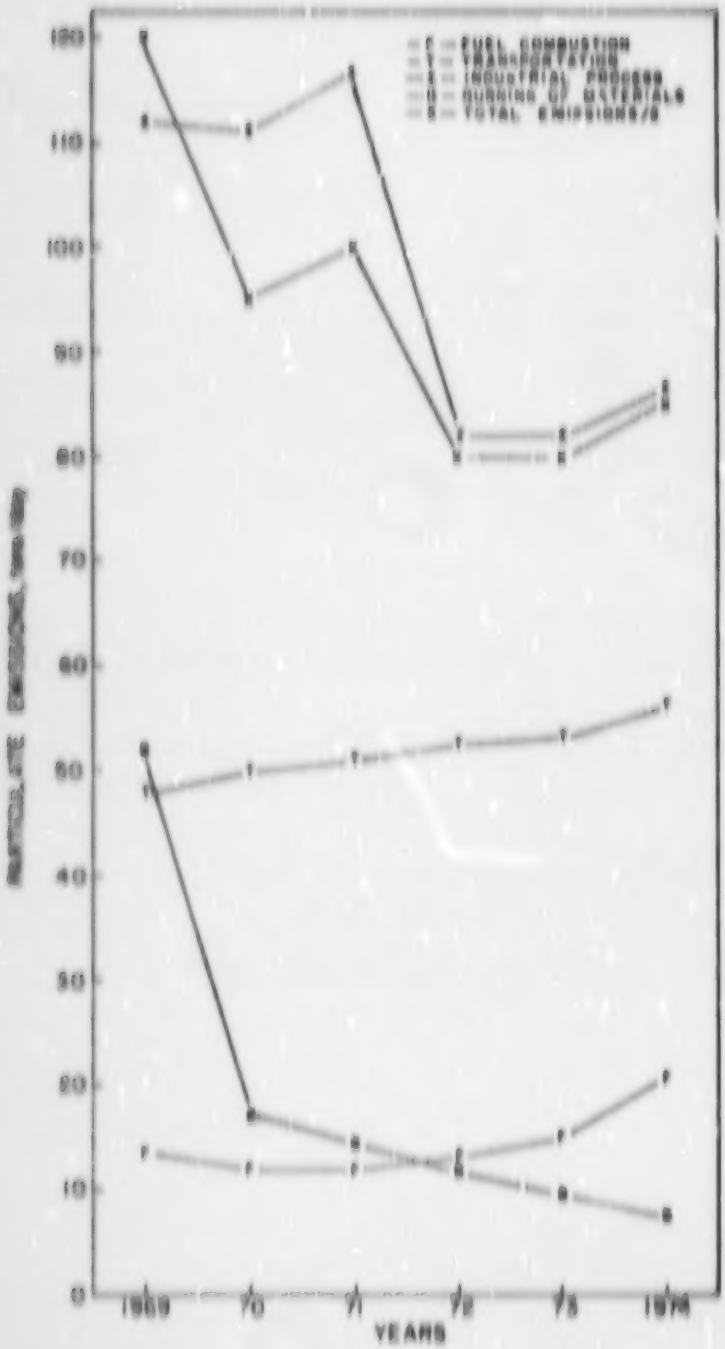


Figure 13. Annual emissions in the BAAPCD by source category, 1969 to 1974

Table 4. ENERGY USAGE TRENDS IN SAN FRANCISCO COUNTY BETWEEN 1950 AND 1973 (DATA AS AVAILABLE)

| | Residential usage,[2] (in number of dwelling units) | | | | | Electric utility usage[3] | | |
|---|---|---|---|---|---|---|---|---|
| | 1950 | 1960 | 1970 | Ratio 1970/1950 | Ratio 1970/1960 | 1964 | 1973 | Ratio 1973/1964 |
| Electricity | 1,335 | 3,417 | 20,776 | 15.56 | 6.08 | | | |
| Gas | 224,090 | 267,802 | 257,439 | 1.15 | 0.96 | 21,394x $10^6$ $ft^3$ | 30,499x $10^6$ $ft^3$ | 1.16 |
| Oil | 2,865 | 3,217 | 4,268 | 1.49 | 1.33 | 91x $10^3$ bbl | 220x $10^3$ bbl | 2.42 |
| Coal | 5,055 | 1,155 | 106 | 0.02 | 0.09 | | | |

Table 5. ENERGY USAGE TRENDS IN THE SAN FRANCISCO - OAKLAND SMSA BETWEEN 1950 AND 1973 (DATA AS AVAILABLE)

| | Residential usage,[2] (in number of dwelling units) | | | | | Industrial usage[4] | | |
|---|---|---|---|---|---|---|---|---|
| | 1950 | 1960 | 1970 | Ratio 1970/1950 | Ratio 1970/1960 | 1963 | 1972 | Ratio 1972/1963 |
| Electricity | 5,625 | 12,478 | 83,030 | 14.76 | 6.65 | | | |
| Gas | 616,738 | 670,040 | 977,246 | 1.59 | 1.22 | 72,997x $10^6$ $ft^3$ | 129,040x $10^6$ $ft^3$ | 1.63 |
| Oil | 25,958 | 12,366 | 7,372 | 0.25 | 0.60 | 2,453x $10^3$ bbl | 660x $10^3$ bbl | 0.27 |
| Coal | 9,558 | 2,678 | 245 | 0.03 | 0.09 | S | .8x $10^3$ tons | |
| Coke | | | | 1.63 | 1.29 | S | 55.6x $10^3$ tons | |

Note: S - data no statistically significant.

monthly arithmetic means over the 5 year period from 1963 to 1967 for the four HASN sites operating in the District at that time.[5] This data signified that the highest monthly averages occurred in December, January, and February with an average of all four stations of over 100 $\mu g/m^3$ during these months; Districtwide averages were in the 70's during the summer (see Figure 14). This is in sharp contrast with the 1974 seasonal TSP pattern (Figures 7 to 9) which had lower levels during the winter. The meteorology in 1974 was not different enough to have caused this to occur. Rather, it is likely to be a result of the decrease in emissions from space heating.

The gradual change that occurred in the seasonal pattern is best observed in Figure 15 which presents the seasonal pattern at the San Francisco HASN site between 1957 and 1974. In the early years, pre-1967, a high winter TSP pattern was prominent through decreasing slightly over this time. Between 1967 and 1971, this pattern became much less noticeable; and, between 1972 and 1974, no such consistent pattern emerges.

Fugitive Dust

The emissions data from the BAAPCD discussed above does not contain any estimate of the emissions from possible fugitive dust sources. Fugitive dust may be expected to result from activities such as land tilling, travel on paved or dirt roads, construction, landings and takeoffs from dirt airstrips, cattle feedlots and land development and is especially important in arid or semi-arid regions such as San Francisco due to the case of eventrainment. A calculation of the preliminary data supplied from a study[6] for a national inventory of emissions of dirt roads, dirt airstrips, construction, and agricultural tilling was conducted in the course of this effort to provide an understanding of the possible contribution from these sources. The results of these calculations, given in Table 6, indicated that over 2 million tons of particulates are emitted each year from these four activities

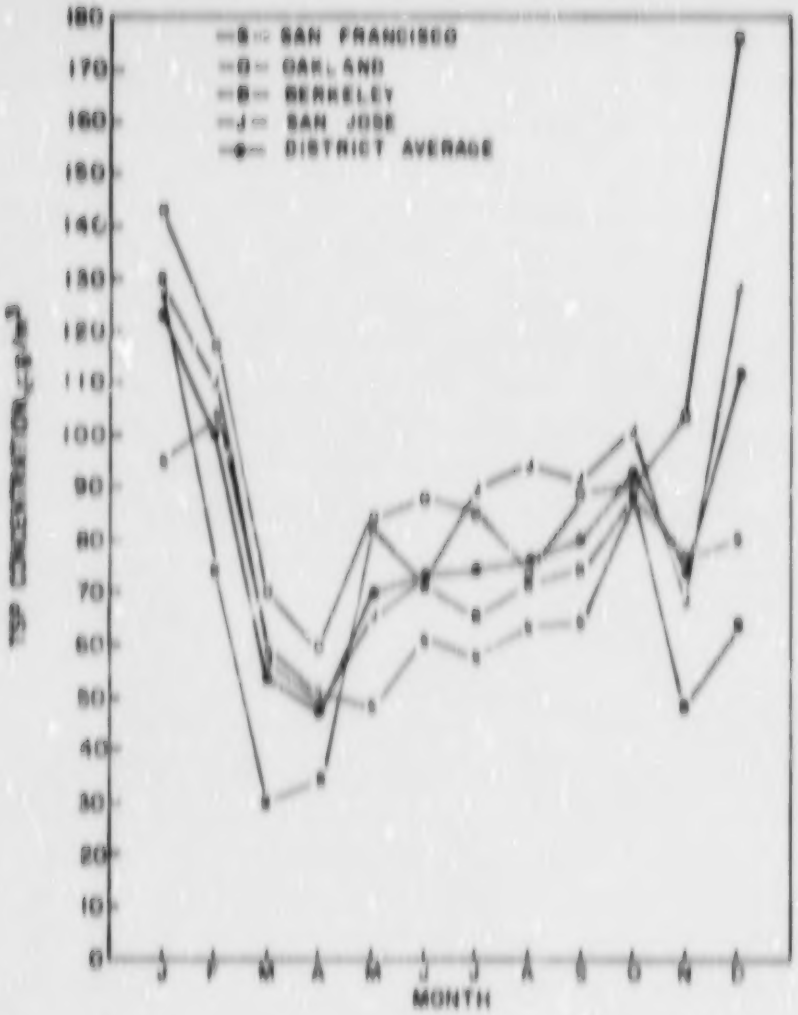


Figure 14. Average monthly TSP concentrations at NASN stations in the BAAFCD, 1963 to 1967

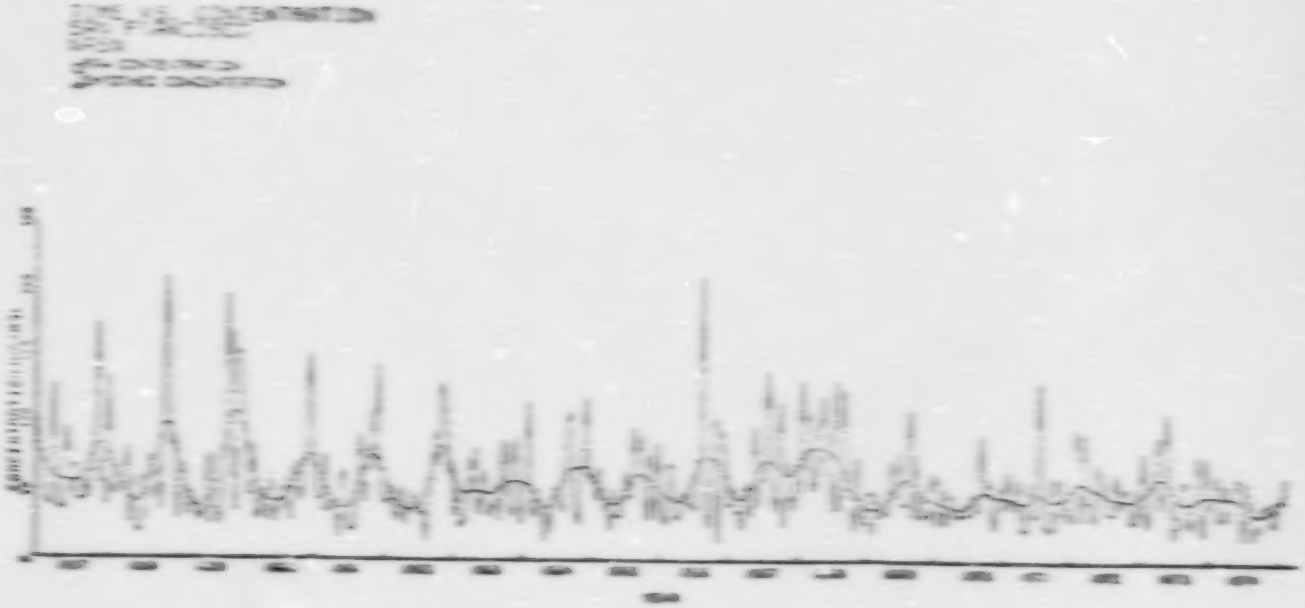

Figure 15. Seasonal pattern in TSP levels at the San Francisco NASN station, 1957 to 1974

Table 6. FUGITIVE DUST EMISSIONS IN THE SAN FRANCISCO BAY AREA AQCR
(IN TONS PER YEAR)

| County | Unpaved roads | Dirt air strips | Construction | Land tilling | Total | Percent of AQCR |
|---|---|---|---|---|---|---|
| Alameda | 40,458 | 0 | 269,500 | 5,099 | 315,057 | 15 |
| Contra Costa | 109,560 | 16 | 187,250 | 8,446 | 305,272 | 14 |
| Marin | 50,820 | 10 | 56,175 | 136 | 107,141 | 5 |
| Napa | 103,620 | 13 | 21,175 | 208 | 125,016 | 6 |
| San Francisco | 660 | 0 | 147,175 | 132 | 147,967 | 7 |
| San Mateo | 32,670 | 0 | 167,300 | 1,390 | 201,360 | 9 |
| Santa Clara | 92,400 | 82 | 274,750 | 10,002 | 377,234 | 18 |
| Solano | 45,936 | 66 | 36,100 | 161,190 | 237,292 | 11 |
| Sonoma | 257,400 | 220 | 57,050 | 2,136 | 316,806 | 15 |
| Total | 733,524 | 407 | 1,310,475 | 188,739 | 2,133,145 | |

in the AQCR, equivalent to over 36 times the inventory of the BAAPCD. The majority of these emissions are contributed from construction activity and travel on unpaved roads. While the use of these values as emissions comparable to those from the BAAPCD are inappropriate given the lack of a major TSP problem in the area, the present contributions from the different sectors within this inventory may be representative.

## LEGAL AUTHORITY, REGULATIONS, AND SURVEILLANCE*

The Bay Area Air Pollution Control District was created by the California Legislature in 1955 — the first regional agency dealing with air pollution to be formed in California. District structure, operating procedures and authority are contained in Chapter 2.5 of Division 20 and Chapters 3, 3.5, 6, 7 and 9 of Division 26 of the California Health and Safety Code. The jurisdiction of the BAAPCD is largely limited to policing nonvehicular sources of air pollution within the Bay Area, primarily industry and burning. Recently it was authorized to cite smoking vehicles, although the main automotive control program is administered through the State Air Resources Board. Aircraft are subject to control through the Federal government.

The District is governed by an eighteen-member Board of Directors. Each county is represented by two members, one selected by the County Board of Supervisors from among their number and the other a mayor or city councilman selected by the City Selection Committee. The Board has the power to develop and enforce regulations for the control of air pollution within the District. The Board appoints a 20 member Advisory Council from community interest groups to advise it and assist it in developing regulations. The District's five member Hearing Board is an

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*Some of the following discussion is taken directly from Reference 7.

independent body which hears pleas for variances from District regulations and accusations against violating sources. Acting as a judicial body, the Hearing Board rules on accusations against sources which have not corrected violating conditions in a reasonable length of time. If, after hearing both sides, it supports the District's argument, an order for abatement is issued against the defendant, which will then be enforced through Superior Court. The Hearing Board's independence from the Board of Directors insures its objectivity in hearing cases brought before it.

The Board appoints the Air Pollution Control Officer, who in turn is responsible for the staff. The BAAPCD employs 224 people and operates on a budget of $5,389,305, most of it derived from local property taxes. It also holds two Federal grants totaling about 10 percent of the budget and $1,000,000 in state subvention funds.

Regulations

The principal objective of the BAAPCD is the attainment and maintenance of both the NAAQS and the air quality standards promulgated by the State, pursuing whichever one is more stringent. California began setting air quality standards in 1969 under the provisions of the Mulford - Carrell Act. A chart comparing these standards with the Federal requirements is given in Table 7. In the case of particulates, California's standards are more restrictive on a 24-hour basis, allowing a maximum of 100 $\mu g/m^3$, and equal to the Federal guide of 60 $\mu g/m^3$ for the secondary annual standard.

Toward this end, the District has enacted eight regulations. Some of them directly control air pollution by limiting the emissions of specific contaminants. Others indirectly control pollutants by curtailing open burning, necessitating process changes to meet direct controls, or by denying construction permits. All rules and regulations to control air pollution must be passed by a majority of the

Table 7. COMPARISON OF FEDERAL AND CALIFORNIA AIR QUALITY STANDARDS[a]

| Pollutant | Time period | Federal standards | | California standard |
|---|---|---|---|---|
| | | Primary | Secondary | |
| Particulate | Ann. avg | 75 $\mu g/m^3$ | 60 $\mu g/m^3$ | 60 $\mu g/m^3$ |
| | 24-hr avg | 260 $\mu g/m^3$ | 150 $\mu g/m^3$ | 100 $\mu g/m^3$ |
| Sulfur dioxide | Ann. avg | 0.03 ppm | | |
| | 24-hr avg | 0.14 ppm | | 0.04 ppm |
| | 3-hr avg | 0.50 ppm | 0.50 ppm | |
| | 1-hr avg | | | 0.50 ppm |
| Carbon monoxide | 8-hr avg | 9 ppm | Same | - |
| | 1-hr avg | 35 ppm | Same | 40 ppm |
| | 12-hr avg | - | - | 10 ppm |
| Oxidant | 1-hr avg | 0.08 ppm | Same | 0.10 ppm |
| Nitrogen dioxide | Ann. avg | 0.05 ppm | Same | - |
| | 1-hr avg | - | - | 0.25 ppm |
| Lead | 30-day avg | - | - | 1.5 $\mu g/m^3$ |
| Hydrogen sulfide | 1-hr avg | - | - | 0.03 ppm |
| Visibility | | - | - | 10 miles or more when rel. humidity greater than 70% |

[a]The strictest air quality standard, whether State or Federal, applies in the Bay Area.

Directors. Public hearings are required prior to any action adopting or amending such rules and regulations. In addition to its regulations the District has the broad power to abate the emission of air contaminants that cause, "... injury, detriment, nuisance or annoyance to any considerable number of persons...or which cause...injury or damage to business or property."

Regulation One, originally promulgated in 1957, lists the rules governing open burning. Regulation Two contains four sections concerning administrative matters, two sections describing analytical procedures, and 10 sections setting various emission standards for industrial processes, including particulate emissions from incinerators, heat transfer operations, combustion sources, and general processes as well as a section on visible emissions. Other specific emissions discussed are sulfur dioxide, hydrogen sulfide, lead, and nitrogen oxide.

The District's permit requirements, set out in Division 13 of Regulation Two, require anyone wishing to build or expand a source that emits air contaminants to first apply to the BAAPCD for a permit to build and submit plans and specifications for evaluation by District engineers. Permits to build will be denied if it is determined that such a facility would not meet any of the District's emission requirements or would cause any air quality standard to be exceeded or if a source related air quality standard is already exceeded in the vicinity of the proposed site. A second evaluation is required after the source is built before it can obtain a permit to operate. This permit procedure is soon to be extended to indirect sources of air pollution.

Regulation Three controls organic compounds, in particular "reactive" organics, by regulating the formulation, storage, shipment and use of such materials as solvents, paint, gasoline and ink. Regulation Four, requiring the installation of crankcase control devices on all 1955-63 model cars upon the transfer of ownership, has been made obsolete due

to recent developments in state law which have imposed similar requirements on a state wide basis. Regulation Five explains the District's air pollution episode plan. It defines the levels associated with each of the four successive stages, Smog Advisory, Alert, Warning and Emergency and explains the actions required for each condition. Regulation Six gives members of the District's Vehicle Patrol the authority to arrest individuals observed to be violating those provisions of the Vehicle Code relating to automotive emissions. Regulation Seven sets emission standards for new or modified sources of air pollution, following EPA guidelines, and Regulation Eight establishes limits for the emission of asbestos, beryllium and mercury.

The specific controls on emissions of particulates from different operators are summarized below.

Visible Emissions - Presently, Ringelmann 1 (20 percent opacity) is the allowable density for smoke, used for evaluation of smoke plumes in the field. Any plume which obscures an inspector's view by more than 20 percent for longer than three minutes in any hour is in violation.

Open Burning - Regulation One bans dump fires and backyard trash burning. It also subjects agricultural burning to meteorological controls. Farmers are allowed to burn their crop wastes during specified seasons on District-approved "burn" days. Exempted from Regulation One's controls are barbeques, recreational fires and fires approved for the purpose of disposing of diseased trees and brush, hazardous materials, fire training, range, forest and wildlife management, flood control and the clearing of undergrowth in irrigation ditches.

Incineration - Emissions from an incinerator with a capacity greater than 100 tons per day are limited to 0.05 grains per standard cubic foot. For an incinerator with a capacity less than or equal to 100 tons per day the emission limit is 0.15 grains per standard cubic foot. The new source performance standard is 0.08 grains per standard cubic foot for incinerators with a capacity greater than 50 tons per day. The incinerators must also meet $SO_2$, $H_2S$, hydrocarbon, and carbonyl emission limitations.

Fuel Burning - Particulate emissions from a combustion operation are limited to 0.15 grains per standard cubic foot (0.25 lbs/$10^6$ Btu) regardless of the size of the facility. The new source performance standard for fossil fueled steam generators is 0.10 pounds of particulate matter per million Btu heat input.

General Processes - The allowable particulate emissions for manufacturing processes are presented graphically in Figure 16 on a process weight rate basis. Exemptions from this weight rate can be granted if the source can demonstrate that it does not exceed a grain loading rate, ranging from 0.10 gr/SCF to 0.02 gr/SCF depending upon the gas volume.

Fugitive Dust - San Francisco does not have a specific fugitive dust regulation, relying instead on control of such sources under an annoyance provision of regulation 2 and Article 10 of the Bay Area Air Pollution Control Law. These controls prohibit a person from allowing particulates of sufficient number and of size large enough to be identified as individual particulates at the source to fall on the property of another, thereby constituting an annoyance.

The plot of the BAAPCD general process regulation in Figure 16 is superimposed on a graph which represents the maximum and minimum controls currently being applied in the United States.[8] The dashed lines in this figure represent the most and least stringent of the regulations in each size category and, as such, do not reflect the controls in any one jurisdiction. The shaded area in this figure reflects the arithmetic mean, plus and minus one standard deviation, of the 14 cities reviewed under this study. This figure indicates that the process weight rate regulation for the District is comparable to the average of the process weight rate regulations in the 14 cities studied. Given the lack of a general TSP problem and a very small industry base, it is not likely that further control would be necessary at this time.

Similar reviews were conducted for regulations governing fuel burning, incinerators, and fugitive dust. The BAAPCD regulation covering fuel

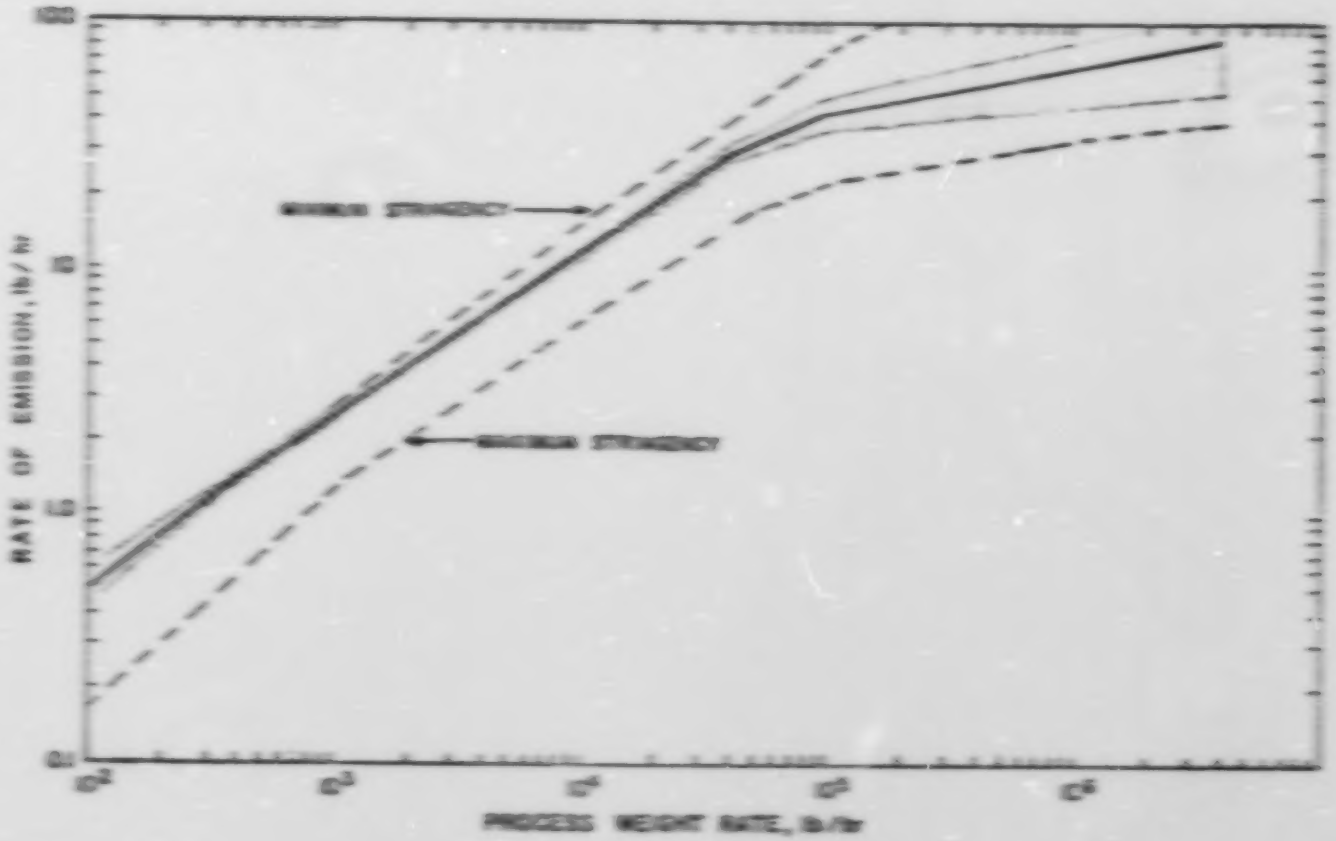


Figure 24. Comparison of stringency of the particulate emission regulation of [illegible] with other controls nationwide - general process

burning was converted to a pounds per $10^6$ Btu rate and plotted in Figure 17 on which a similar relative stringency determination had been made. The standard for fuel burning equipment is given in a constant grains per standard cubic foot and so does not vary as heat input increases. This makes the Bay Area's emission standard as stringent as the other cities studied for smaller sources (up to 30 million Btu/hr input) and more lenient than average for larger sources.

The regulations for visible emissions and incinerators were found to be comparable with most other areas with incinerator controls being more stringent than average for the larger sizes (greater than 100 tons of refuse per day). The fugitive dust regulation is only as stringent as the BAAPCD desires to enforce it. Fugitive emissions from "any emission point which is not an intended opening, and from which no significant quantities of air contaminants are emitted" are exempt from control.

Surveillance Procedures

The District's 40 air pollution inspectors patrol assigned territories and determine whether or not stationary sources are complying with District regulations. Each inspector must inspect all sources in his territory regularly, maintain liaison with industrial representatives and local health and fire officials as needed, and investigate citizen complaints. Source surveillance is on a dawn-to-dusk, 7 days a week basis, however, night inspections are used periodically. Inspectors keep in touch with District headquarters in San Francisco by radio.

District inspectors issue violation notices in making their rounds whenever they detect evidence of emissions in excess of the levels allowed by the regulations. These violation notices contain the date, time, place and type of violation as well as an order that the offender explain the cause of violation within 10 days. Violation notices are

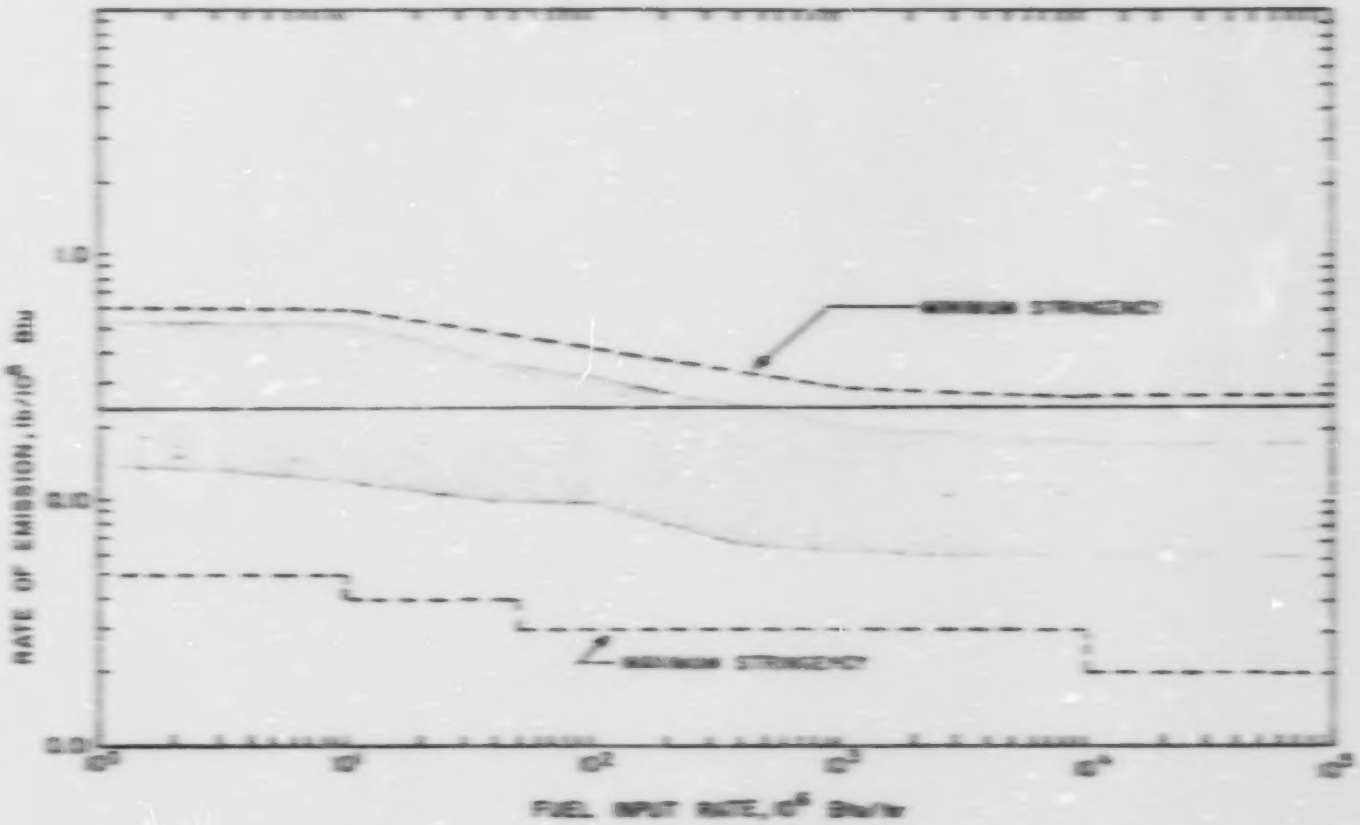


Figure IV. Comparison of stringency of the particulate emission regulation of BAPCD with other controls nationwide - fuel burning

also issued as a result of source tests of industrial effluent, which are analysed in the laboratory, or from data recorded at the ground level monitoring networks, which surround factories that produce sulfur gases. Five inspectors are also on full time duty, one each, for the refineries in the District.

The District may seek civil penalties under Health and Safety Code Section 39261 for violations of any of its regulations. Also, under Health and Safety Code Section 24369 it may seek civil penalties of up to $500 per day, not to exceed $5,000 for any 30-day period, for violations of Regulation Two. Open burning violations (Regulation One) are normally processed under Health and Safety Code Section 39261, but can also be treated as misdemeanors by the District. Violators are subject to up to $500 fine and/or 6 months in jail under Health and Safety Code Section 24361.5.

The BAAPCD cannot of its own volition levy fines on a violating company or shut one down. These actions must be brought to the courts and litigated in accordance with due process of law. In these cases the District must be prepared to prove intent, negligence and, sometimes, an unwillingness to cooperate within a reasonable time.

The enforcement procedure of the Vehicle Patrol is much simpler. Citations are issued to the drivers of vehicles which emit excessive smoke. These citations are notices to appear and may require that proof of correction be submitted to traffic court along with the amount of the fine imposed. Fines vary from 0 to 50 dollars depending on local court policy. As with traffic citations, bail can be forfeited and remittance made by mail. Failure to correct can result in further action by the court. In 1974, an average of 300 tickets were issuud each month.

Most all sources in the District have been determined to be in compliance with respect to particulate matter. While most of these determinations are made through calculations of input and operating parameters, within the past couple of years final compliance of larger sources has been checked primarily through source tests. The Source Test Section of the BAAPCD conducts 300 to 400 tests at smoke stacks and other emission points each year.

Scheduling plant inspections and tests is done via a computer system which automatically determines the frequency of visits based on the pollution potential of the source. The system gives higher priority to large sources, sources on compliance schedules, and sources against which complaints have been filed. Visits are usually scheduled quarterly for large sources down to once every two years for sources with very low potential. Currently over 70,000 pieces of equipment are on file in the system.

Conclusions

A review of the BAAPCD regulations and enforcement program indicated that a quite active program exists in the area, apparently maintaining complete and up-to-date files on most sources in the area. While the particulate regulations are not the most stringent of those observed in the course of this study, they seem appropriate given the degree of the TSP problem in the District. The only possible area of difficulty noted was in the lack of a specific fugitive dust regulation which may be needed during the more arid times. In addition, care must be taken to not ignore particulate sources for the sake of controlling sources of organics and other pollutants which are a more serious problem for the Bay Area.

## NETWORK DESIGN

The monitoring network for the District (Figure 5) is designed to identify the TSP concentrations (and other pollution levels) to which the general population is exposed. Therefore, most monitors are located in areas classified as center city-commercial whereas four stations are in industrial areas. Because of the widespread nature of the District, an analysis of only 12 of the sites, selected as representative and of primary interest, was conducted.

Of the sites visited, most monitors were well situated with respect to ventilation and exposure. Specific comments on the siting of each monitor are made in Table 8 which groups the monitors by the predominant characteristic of the neighborhood of each. This table also provides the height of each monitor, its approximate slant distance from the nearest major road, and the geometric mean for each station. Individual sites are elaborated on below.

Two major differences from the other cities reviewed were noted in the operation of the monitoring network for the Bay Area. First, they used two types of sampling media in the hi-volume air samplers. Traditionally, the BAAPCD has used Whatman 41 filter paper on which they perform their own analyses for metals, sulfates, and other pollutants. However, because the glass fiber filter has become the more standard sampling media nationwide, they are now sampling every 6th day with glass fiber and also every 6th day with Whatman 41 in their normal sampling schedule of once every 3 days. In addition, the BAAPCD was the only agency that was using flat-roofed hi-vols as well as the more usual gable roof. Comparative analyses by the BAAPCD did not identify any significant differences between either the two sampling media or the two roof configurations with respect to the total mass of particulate matter collected.

Table 8. CHARACTERISTICS OF BAAPCD MONITOR SITES REVIEWED

| Neighborhood | Map code | Location | 1974 Annual geometric mean, $\mu g/m^3$ | Height above ground, ft | Slant distances, ft | Siting comments |
|---|---|---|---|---|---|---|
| Industrial | PT | Pittsburg | 50 | 20 | 25 | Well exposed site, industry to the south, gravel parking lots on both sides of building, lumber yard possible source of small fugitive emissions. |
| | OK | Oakland (BASE) | 52 | 62 | 70 | Trucking terminals and light industry in area, 1-71 25 yards to north. |
| | SFE | East San Francisco | 86 | 30 | 60 | Trucking terminals, and light to moderate industry area, good exposure. |
| Commercial | LFR | San Francisco (BASE) | 51 | 32 | 40 | Located in civic center area, heavy traffic. |
| | SF | San Francisco | 53 | 15 | 40 | Poor exposure, building directly to west of monitor, monitor surrounds on all four sides to height of 3 feet, window box with dirt at intake level 3 feet to east, gas station stack 50 feet to ENE. |
| | SU | Sunnyvale | 41 | 33 | 150 | Good exposure back from road, in parking lot, no obvious sources. |
| | RC | Richmond | 58 | 17 | 95 | Poor exposure in corner of gravel roof, heavy traffic, problems with motorcycle activity on nearby dirt lot. |
| | RC | Redwood City | 50 | 11 | 46 | Good exposure all directions, medium to heavy traffic, trucking terminals in area. |
| | LZ | Livermore | 74 | 19 | 35 | Good exposure to large amounts of fugitive dust - dirt parking lots, gravel pits, highway construction, etc., no major industry noticeable. |
| Residential | BK | Berkeley (BASE) | 30 | 90 | 100 | Commercial to residential area, heavy traffic. |
| | SJ | San Jose | 59 | 15 | 45 | Good exposure, heavy traffic, gravel parking lot 30 feet to SE. |
| | FR | Fremont | 58 | 16 | 35 | Good exposure, light traffic and little activity in area, dirt field 50 yards to SE. |

An example of a flat-roofed hi-vol can be seen in Figure 18. This picture reflects the station in Richmond which was considered to be a poorly ventilated site due to the location of the sampler in the corner of the roof up against a parapet. This arrangement would probably prevent equal exposure to winds from the south and east; similarly, the slanting roof to the north would interrupt air flow from that direction. Other problems may arise due to the gravel roof and the vortexes that could be generated in such corners.

Figure 18. Richmond hi-vol site

The only other monitor in the District that was reviewed in this effort and found to be poorly sited in terms of ventilation is the BAAPCD site in downton San Francisco. The hi-vol at this site is located on a walled in overhang jutting out from a floor used as a garage. The building, 5 feet to the west of the hi-vol, rises about 80 feet above the overhang. The walls of the overhang, within several feet of the monitor, are approximately 3 feet high and the east wall contains a window box with loose dirt in it. The location of this hi-vol is pictured in Figure 19.

Figure 19. Hi-vol site at 939 Ellis Street

The levels measured at the station in Livermore were the highest of any of those reporting a full years worth of data in 1974. At 74 $\mu g/m^3$, it was only 2 $\mu g/m^3$ away from a violation of the primary annual NAAQS for particulates and was exceeding the State's annual standard by more than 23 percent. Yet the monitor was not located near any great amounts of industrial or other major activity. The visit to the site indicated that the high levels must be a result of fugitive dust in the generally dry climate. Local sources of fugitive dust included a gravel yard, road construction, unpaved roads and parking lots, holding pens, and a railroad bed.

Difficulty with evaluating the air quality data in relation to emissions is partly because of the low density of monitors in the BAAPCD. While the number of monitors are sufficient to meet federal requirements, the density of monitors was the lowest of the areas studied. This is likely the result of the data to date which illustrates the lack of any major problem with TSP in the District. Recent efforts at developing a model for the area should help in determining if additional sites are needed.

Similarly, the selection of neighborhoods for monitors appeared to be oriented toward commercial areas as opposed to industrial areas, normally considered to have higher particulate levels. The expansion of the monitoring network into East San Francisco, a light to moderate industrial area, may illustrate this point. A comparison of the geometric mean of 57 samples taken concurrently at the BAAPCD San Francisco (SF) site and the East San Francisco (SFE) in August 1974 and January through June 1975 indicated that the levels at SFE (49 $\mu g/m^3$) were more than 16 percent higher than the SF site (42 $\mu g/m^3$). Although concurrent sampling days were not available, and therefore the comparison not as valid, a much greater difference was noted for the months of August through October and December of 1974. During this period, the

geometric mean at the SFE monitor (85 $\mu g/m^3$) was more than 55 percent higher than that at the SF site (54 $\mu g/m^3$). Even with the 16 percent difference, the SFE site would be violating the secondary annual standard. Again, an extensive modeling system may help to identify such areas of possibly higher concentrations.

## METEOROLOGY AND CLIMATOLOGY

The general meteorology of the area appears to be one of the dominant factors in determining the day to day and month to month levels of TSP in the San Francisco Bay Area AQCR. This is especially true since the emission levels are fairly constant from month to month. Numerous meteorological parameters were investigated for San Francisco including the yearly and monthly variations in precipitation and space heating demands (degree days), the average wind speed and number of days of precipitation each month, and other ventilation characteristics of the region such as mixing height, inversions, and the movement of air masses through the region. Those factors which are known to be most influential for air quality levels - ventilation and precipitation - were found to be the same ones with the greatest seasonal variation. In addition, each of these factors complement each other, both acting to cause increased levels of particulates in the summer and fall. Therefore, the following discussion focuses primarily on precipitation and ventilation. Supporting data on various meteorological parameters are presented graphically in the appendix.

### Ventilation

The topography of the region significantly affects the climatology and meteorology, having its major effect on the ventilation. A detailed study of the impact of the topography on the ventilation, specifically the channeling of air, was made as part of the Civil Defense program in the 1950's. A summary of the findings are presented below.

"The topographic features of the San Francisco Bay Area have been aptly described as a misshapen celery dish. One lobe of the 'dish' extends southeastward into the mouth of the Santa Clara Valley. Another lobe is the low level opening through the Carquinez Straits area and the third and fourth lobes being the Napa and Petaluma valleys. Elevations of 1500 feet are common in the higher terrain encompassing this area. It can readily be seen that normal wind flow over the area would be radically distorted in the very low levels. This is particularly true when the airmass is stable and the wind velocity is not unusually strong. With stronger wind movement and unstable airmasses moving over the area this distortion becomes much less. The distortion is greatest when low level inversions are present with the surface air, beneath the inversion, flowing independently of the air above the inversion. This latter condition is very common in the summer, the surface airmass being the sea breeze.

"The distortion in wind flow results in major surface wind streams following the lines of least resistance which are in most cases the sea level portions of the area. Encountering obstacles in the terrain the air streams split still tending to follow the low land, such as certain northeasterly winds flowing throught the Carquinez Straits area thence southwestward into the Bay Area but splitting with a branch stream flowing into the Napa and Petaluma Valley areas. Numerous westerly types have the major stream flowing across the San Francisco Peninsula hills splitting in the Oakland-Berkeley areas, one stream flowing southeast throughout the South Bay Area, the other flowing to the northward into the North Bay Area then possibly splitting again with one stream flowing eastward through the Carquinez Straits, another flowing in an eddy curl from the southeast into the northern Marin County and Petaluma valley area. Further distortion takes place in the nature of localized eddy patterns, and deviations in flow with increasing velocities through gaps in the hill sections."[9]

The impact of topography on the meteorology renders special techniques such as pollution roses inappropriate because of the wide differences that could be occurring at any site for which wind direction is not recorded. While the topography also acts to influence other characteristics of ventilation, the global-scale weather can strongly affect

these local variations. When strong jet-stream winds dominate the air-flow above California, or when migratory storms bring rain and upward vertical flow, the air pollution concentrations are very low. When high pressure areas dominate California, resulting in light winds and downward vertical flow, heavy build-ups of pollution are common.

The amount of air available to dilute pollutants depends primarily on two factors, the horizontal airflow and the vertical mixing. The strong inversions typical of California summers are caused by downward vertical motion, called subsidence, which compresses and heats the air. The surface inversions typical of winter are formed by radiation as air is cooled in contact with the earth's cold surface at night. The summer subsidence inversions persist throughout the day, and occur over 90 percent of the time. The winter radiation inversions occur on over 70 percent of the nights but are usually destroyed by heating in the afternoon, bringing rapid improvement in air quality. Both types of inversion mechanism may operate at any time of the year, and in the fall both may combine to produce the heaviest pollution potential.

In its monthly "Contaminant and Weather Summary", the BAAPCD publishes daily and monthly average measures of the degree of vertical mixing called the stability factor. The stability factor is temperature (degrees F) at 2500 feet minus that at the surface so that vertical mixing decreases as the stability factor increases. These factors representing low-level inversion strength are measured at Oakland, San Rafael, and San Jose. The monthly average reported in 1975 for each of these sites are plotted in Figure 20. A comparison between this figure and the monthly TSP patterns presented in Figures 7, 8 and 9 suggest a strong correlation.

As mentioned above, stability, or vertical mixing, is not the only important parameter in determining the volume of air available for dispersing the pollutants. The horizontal air flow (wind speed) is

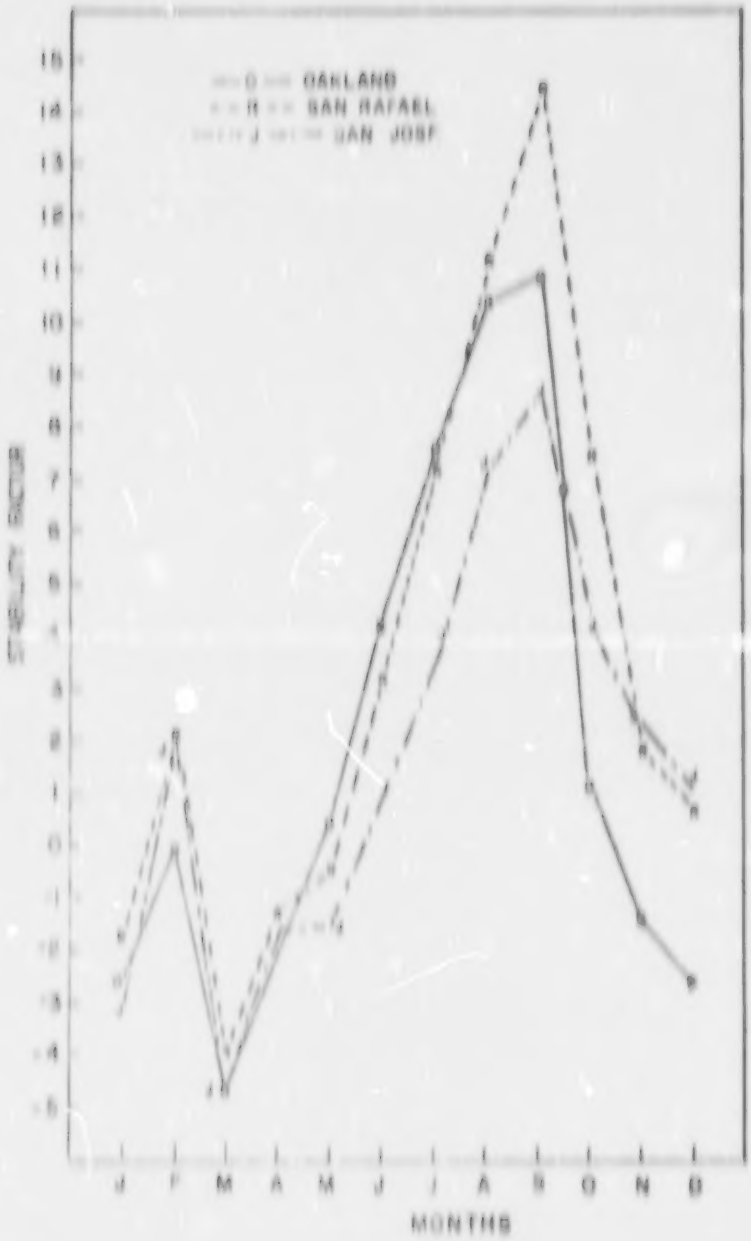


Figure 20. Monthly average stability factors at three sites in BAAPCD - 1973

equally important. Together, the wind speed and the stability determine the ventilation factor. The BAAPCB has derived their air measure of the ventilation using the Oakland radiosonde data on a 1 to 5 scale of increasing intensity, with airflow direction at the 1000 millibar level. A monthly ventilation index is calculated from this data and is plotted in Figure 21 for 1974 along with the normal value. When the ventilation index is small, the volume of air available for dilution is also small so the pollution levels are expected to be higher. This figure indicates that not only is the ventilation less during the summer to early fall months when the TSP concentration is higher, but also that the ventilation throughout 1974 was less than the normal ventilation. This would imply that TSP levels were higher in 1974 that would normally have been expected.

Precipitation

Precipitation is normally considered to be the meteorological parameter which has the maximum impact on air quality levels, aside from ventilation rate. It helps to clean the air of particulates through washout and rainout and can suppress the rise of pollution levels by wetting down particulates that would be resuspended if dry or even washing particulates off the streets into sewer systems if the rain is heavy enough. The expected relationship is one of inverse correlation with the pollutant concentration. San Francisco has a well defined seasonal pattern of precipitation with 0.01 to 0.15 inches of precipitation in the summer months and 3 to 4 inches in the winter months on a normal basis. In 1974, this trend was consistent with less than 0.01 inch of precipitation recorded in May, August, and September.

Because of the expected inverse relationship between TSP concentration and precipitation, Figure 22 provides an inverse graph of the precipitation during 1974 by dividing the average monthly (annual/12) by the actual monthly precipitation in 1974 (plotted on log scale to fit

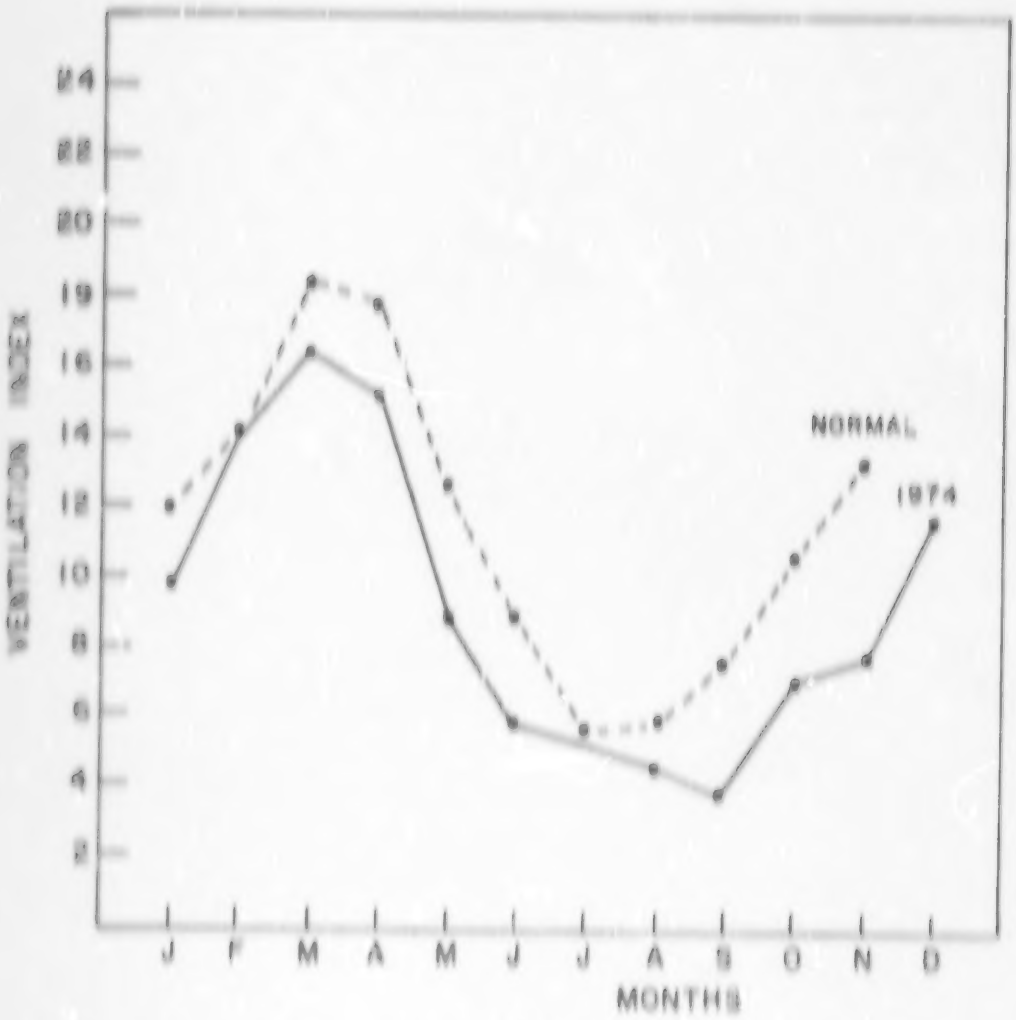


Figure 21. Monthly average ventilation index in the BAAPCD

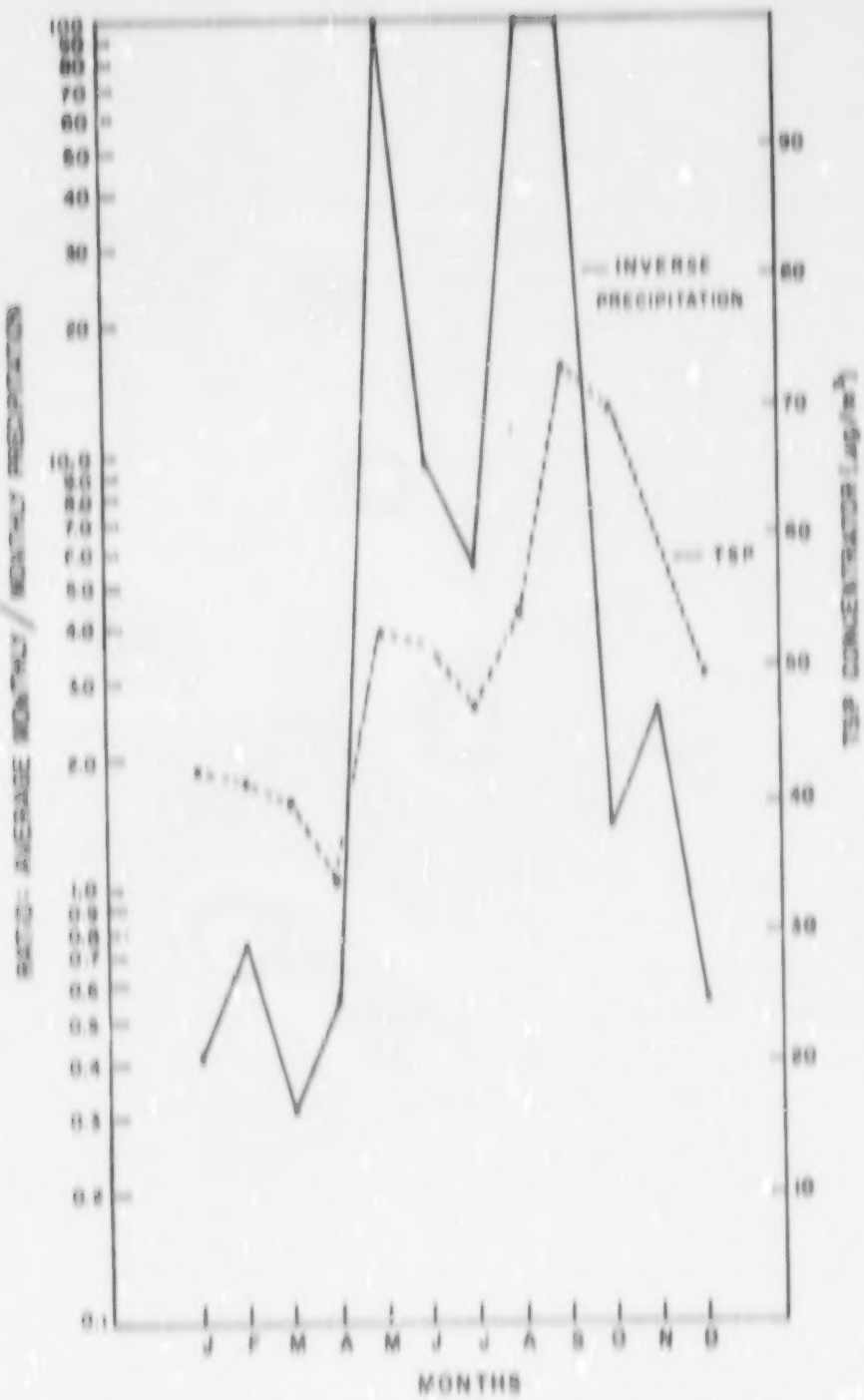


Figure 22. Average monthly/monthly precipitation and districtwide average TSP levels in the BAAPCD 1974

the graph). Overlayed on this graph is a plot of the average monthly geometric mean for all the monitors in the BAAPCD that operated for the full year. This District average is utilized to discount major influences that certain activities may have on individual sites. The degree to which the inverse precipitation graph and the TSP concentration rise and fall together provides an indication of the correlation of the two parameters. The most pronounced characteristics of the precipitation plot are closely paralleled by the seasonal pattern in TSP.

This correlation may be considered as significant as that for ventilation. In addition, the daily pattern of precipitation may be used to better understand the impact that rainfall has on TSP levels. While Figure 22 would indicate that the rainfall in October was a sufficient amount to have a lower average TSP concentration for that month, over 90 percent of the precipitation in October 1974 occurred within the last 5 days of the month and other rainfall came within 5 hours on the first and second day of the month.

Just as precipitation has an impact on the short-term seasonal pattern of TSP concentrations, it can also affect the longer-term annual trends if the total level of precipitation varies significantly from year to year. In recent years in San Francisco, the precipitation has fluctuated more than 50 percent on either side of the normal amount. This has led to differences of more than 100 percent between 2 consecutive years. However, despite these large differences, no significant correlation was noted between the annual TSP levels and the annual level of precipitation.

URBAN ACTIVITY

Beyond industrial activity, fuel combustion, and other traditional pollution sources, it is increasingly apparent that in many locations other urban activities, such as routine traffic and construction and

demolition activities, are a more major part of urban pollution problems than had been previously recognized. Much of this problem is reflected in monitors located close to the activity generating the particulates - street level monitors are influenced by traffic levels, monitors in sections of cities undergoing urban renewal have higher levels than would be expected. Similarly, some monitors in arid climates are impacted by windblown dust and, in the case of San Francisco and other ocean side cities, some contributions from sea salt can be expected. Data was available in the San Francisco to study both the impact of monitor siting with respect to distance from street level and the contribution of dust and salt to the concentration of TSP.

Traffic and Monitor Siting

At the current location of the BAAPCD San Francisco hi-vol (939 Ellis Street), the BAAPCD ran 108 sets of paired measurements during the first 8 months of 1971 comparing the current site, located approximately 15 feet off the ground and 40 feet back from the street, with a site located on top of the building, 93 feet above street level. A picture of the building and the vicinity was given in Figure 19. As discussed earlier, the current hi-vol is located poorly in terms of ventilation of the site. This poor ventilation may lead to lower values, especially if much of the particulate is emitted as a result of traffic.

On all but 7 of the observation days, concentrations at the lower site exceeded those measured at the top of the building. The geometric means of all the paired observations at the two stations were 47 and 42 $\mu g/m^3$, respectively. These paired observations are plotted in Figure 21 to demonstrate the degree to which the monitor closest to the street is measuring higher levels.

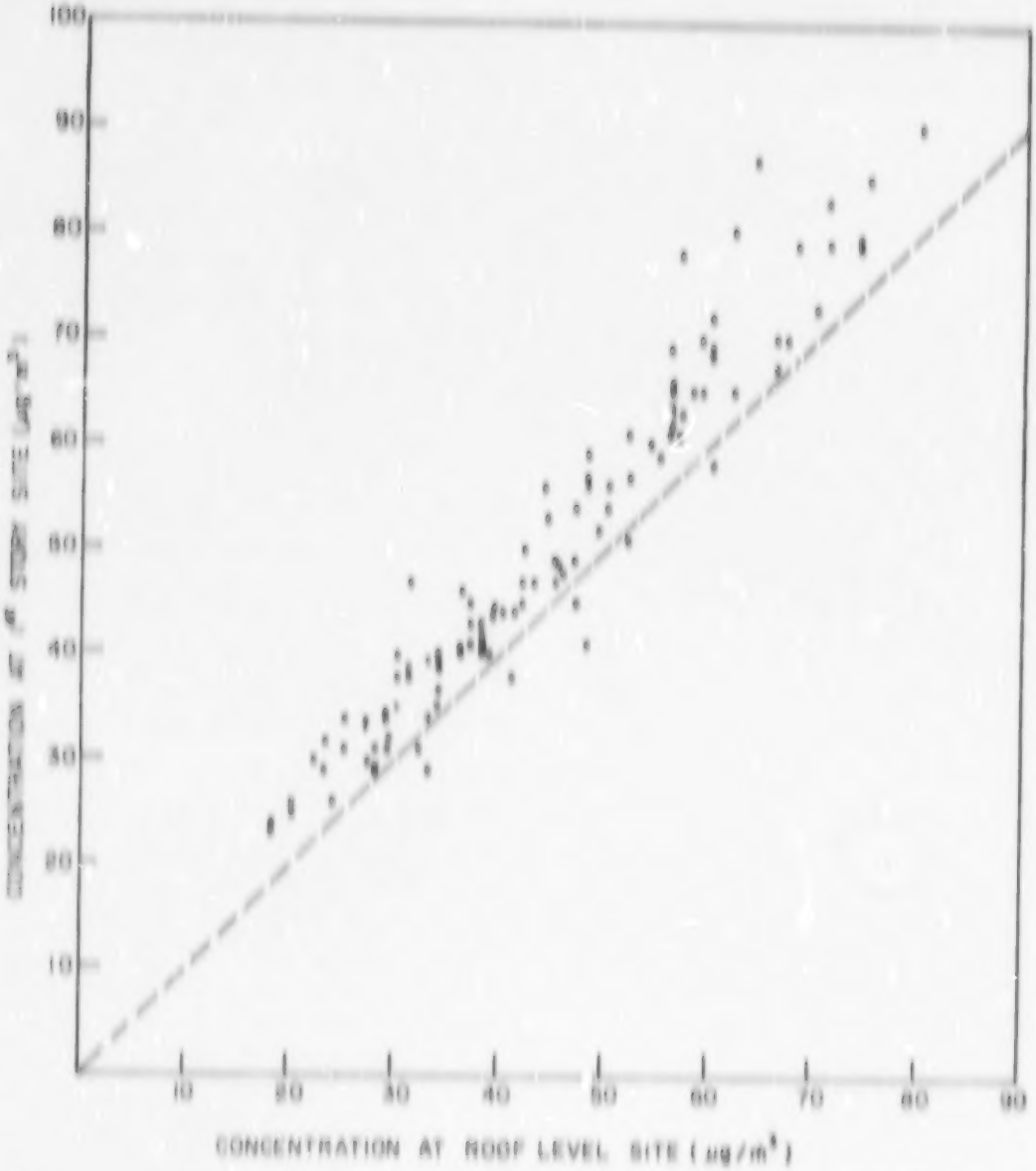


Figure 23. Comparison of impact of height on measured TSP levels at 939 Ellis St., San Francisco

Natural Contribution to Particulate Loadings

In a study conducted by the BAAPCD,[10] analyses of filters were conducted to determine the levels of chloride and silicate on hi-vol samples. The chloride components of TSP were assumed to reflect levels of NaCl (1.67 times the chloride measurements) resulting from salt spray from the ocean. The silicate components (1.75 times $SiO_2$) measurements) were attributed to windblown dust. Both of these components were felt to represent natural sources of particulates and they could therefore be subtracted from the TSP levels to give a level of suspended particulates due to man's activities, or total anthropogenic suspended particulates (TASP).

The mean values from analyses of 21 months of filter data collected at eight stations in the District are given in Table 9. The interpretation of the data reflects what would be expected from a study of the topography and land use in the District. The highest levels of chloride were found in San Francisco which is surrounded on three sides by saline water and the lowest levels were at those sites most inland - Livermore, Pittsburg. The sites at which the contribution from silicates was the highest was exactly the opposite with Livermore, a definite candidate for fugitive dust impact, having over 38 percent of its TSP level coming from silicates.

It should be noted that there are difficulties with this analysis. First, it does not take into account biological and other components that are not anthropogenic. In addition, the assumption that all silicates are naturally caused is faulty. Much of the current activity around the Livermore site would generate siliceous particulates (sand and gravel handling, dirt roads, highway constructions) and these should not be considered naturally occurring. However, the analysis does support the contention that much of the particulate problem at those sites that have one, is not primarily a result of traditional sources.

Table 9. MEAN TOTAL ANTHROPOGENIC SUSPENDED PARTICULATES (TASP) AT EIGHT BoAPCD STATIONS, AS ADJUSTED FOR $SiO_2$ AND Cl COMPONENTS[10]

| Location | Lab code | TSP mean $\mu g/m^3$ | $SiO_2$ x1.25 $\mu g/m^3$ | Cl x1.67 $\mu g/m^3$ | TASP mean $\mu g/m^3$ | % Non-anthropogenic |
|---|---|---|---|---|---|---|
| San Francisco | SF | 54.0 | 7.1 | 7.0 | 39.9 | 26.2 |
| San Rafael | SR | 58.7 | 21.0 | 3.3 | 34.4 | 41.5 |
| Richmond | RI | 65.0 | 14.8 | 4.7 | 45.6 | 29.9 |
| Pittsburg | PT | 71.6 | 27.2 | 2.0 | 42.3 | 40.7 |
| Fremont | FR | 80.7 | 20.1 | 4.2 | 56.4 | 30.1 |
| Livermore | LI | 73.3 | 28.2 | 2.8 | 42.2 | 42.4 |
| San Jose | SJ | 80.1 | 21.2 | 4.0 | 54.8 | 31.5 |
| Redwood City | RC | 65.3 | 18.0 | 4.3 | 42.8 | 34.5 |
| | Avg | 68.2 | 19.2 | 4.2 | 44.8 | 34.3 |

## REFERENCES


1. Source Inventory of Air Pollutant Emissions in the San Francisco Bay Area - 1973. Bay Area Air Pollution Control District, San Francisco, California.

2. U.S. Census of Housing, 1950, 1960, 1970.

3. Steam Electric Plant Factors, 1965 and 1974. National Coal Association, Washington, D.C.

4. U.S. Census of Manufacturers, 1963 and 1972.

5. Suspended Particulates in the San Francisco Bay Area, 1957-1967. Technical Services Division, Bay Area Air Pollution Control District. Information Bulletin 6/13/69.

6. Cowherd, C. C., et al. Emissions Inventory of Agricultural Tilling, Unpaved Roads and Airstrips, and Construction Sites. Prepared for the U.S. Environmental Protection Agency, Office of Air and Waste Management, Office of Air Quality Planning and Standards. November, 1974.

7. Air Pollution and the San Francisco Bay Area. Bay Area Air Pollution Control District. Ninth Edition. January 1975.

8. Martin, W. and A. C. Stern. The World's Air Quality Management Standards. Volume III The Air Quality Management Standards of the United States, U.S. EPA, October 1974. EPA-650/9-75-001-b.

9. A Study of Air Flow Patterns in the San Francisco Bay Area. Technical Services Division, Bay Area Air Pollution Control District. Information Bulletin 6/15/70.

10. Levaggi, D. A., et al. Total Anthropogenic Suspended Particulate as Derived from Chemical Analyses of Chloride and Silicate on High-Volume Samples. Bay Area Air Pollution Control District, 1974.

## SECTION III

## CONCLUSIONS

Currently, the San Francisco Bay Area AQCR does not have a major problem with particulates. No monitor violates either the annual or the 24-hour primary standards (only one value over the 24-hour standard at three stations). The secondary standards are violated, however, at six of the stations for the 24-hour standard and two of the stations for the annual standard ("guide"). The highest annual value reported was at Livermore with a geometric mean of 74 $\mu g/m^3$ in 1974 and this high level is felt to be due mainly to the contribution of fugitive dust in the vicinity of the monitor.

Long-term trends in both emissions and TSP levels have been fairly consistently downward. The current level of emissions at 150 tons/day is one of the lowest of the areas studied and this level is one of the principal factors contributing to the attainment of standards in the area. While controls on sources are not the most stringent of the cities studied, they appear to be adequate at this time. Additional growth and development in the District may require more stringent controls in the future. Two categories where further control may be warranted are fuel combustion and fugitive dust.

Emissions from fuel combustion are expected to become more important over time because of problems with clean fuel availability. Previously, when more coal was burned in the District, the impact was so great as to cause higher levels of TSP in the winter; the reverse is now true. Large fuel burning sources, the first to switch away from natural gas, are also the sources controlled to the least extent.

Since fugitive dust is a problem at Livermore and other rural sites, the BAAPCD may need to consider promulgating regulations directed at these type of sources. While currently these sources can be controlled under the category of nuisance emissions, specific requirements for control measures are often easier to understand and enforce.

At the moment, the BAAPCD appears to have done an adequate job in the attainment of standards and is pursuing further studies on the particulate problem through laboratory analyses. Also, the development of a modeling program for the area should be a useful tool for maintenance planning.

# APPENDIX A

# METEOROLOGICAL DATA

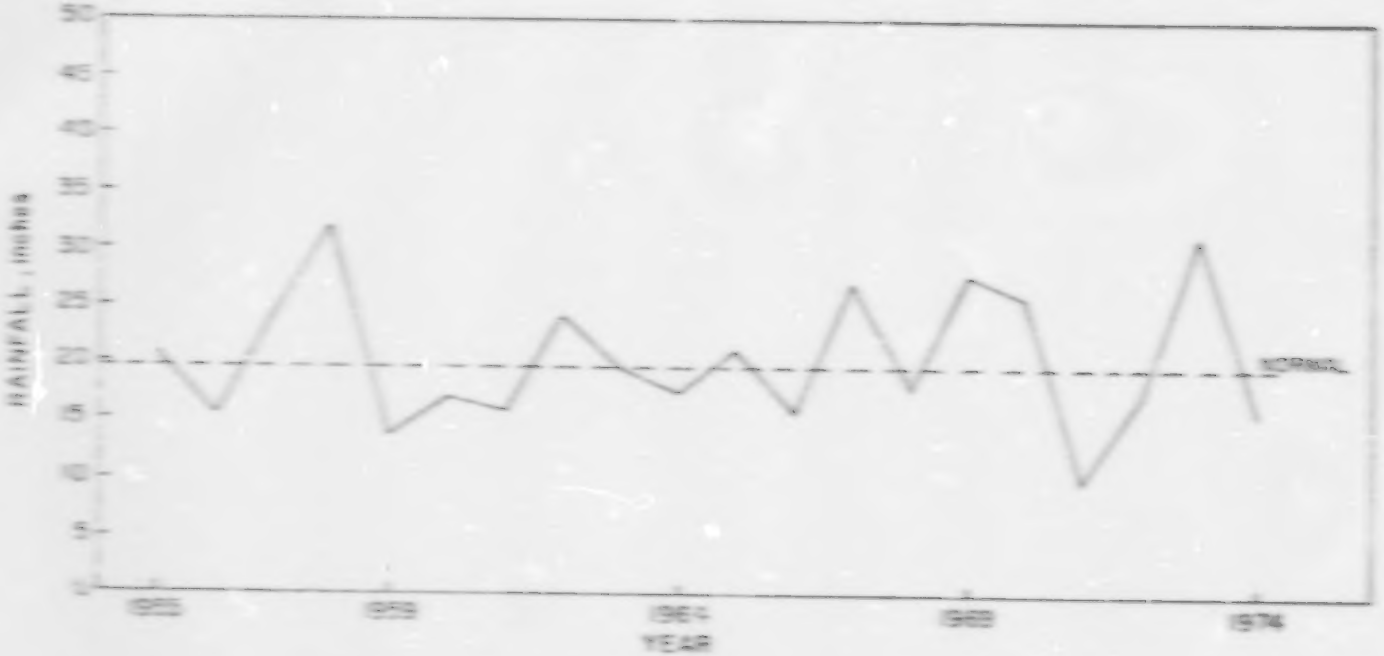


Figure A-1. Yearly rainfall in San Francisco

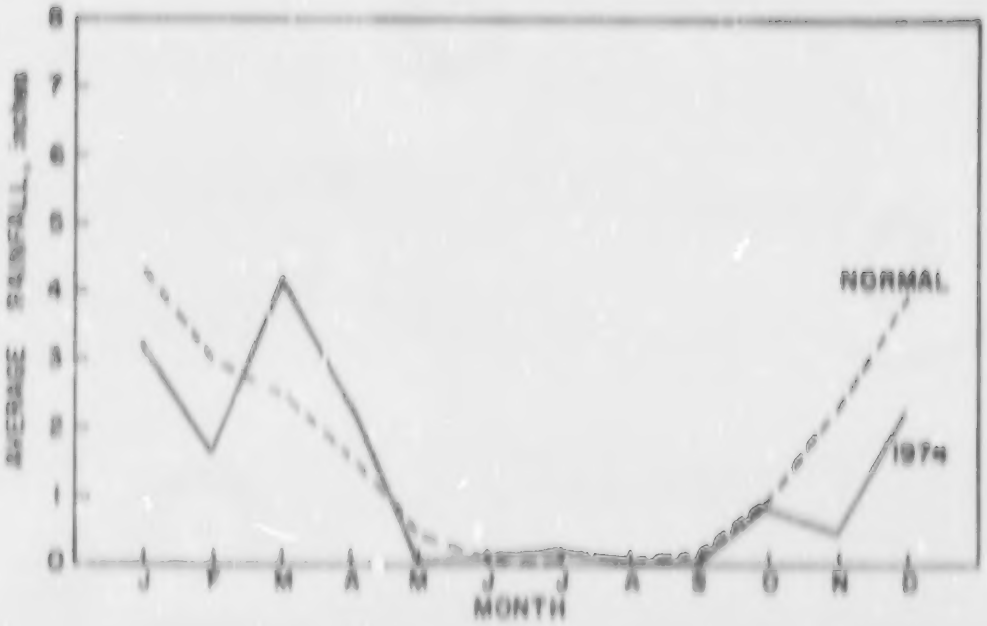


Figure A-2. Monthly rainfall in San Francisco

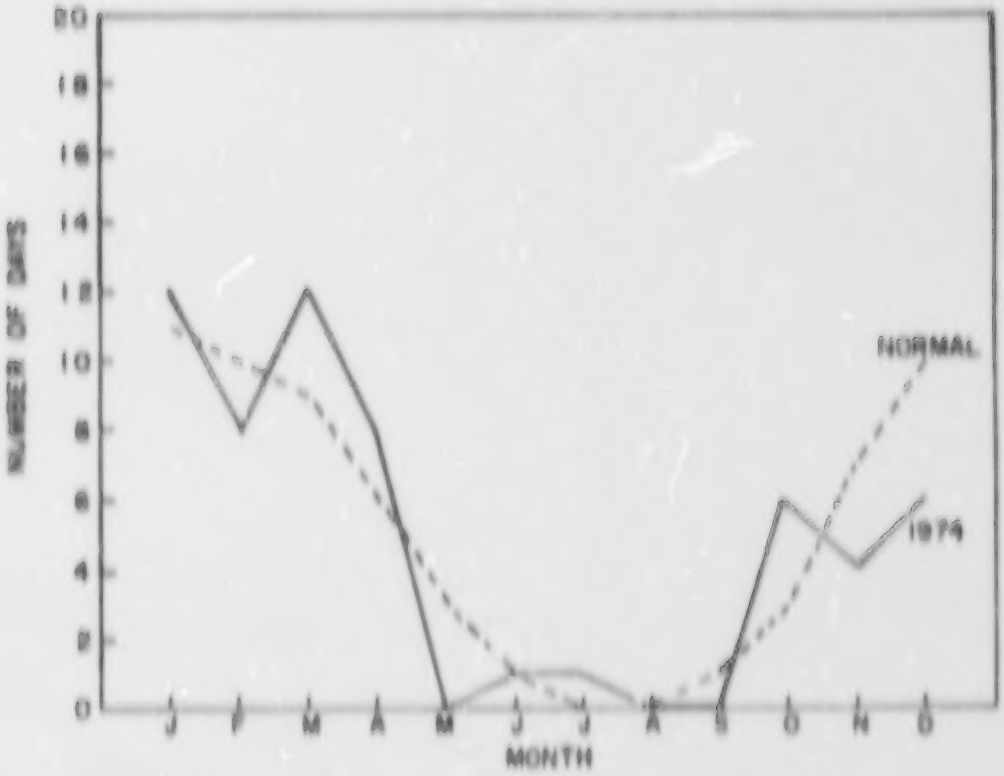


Figure A-3. Monthly number of days of rain in San Francisco

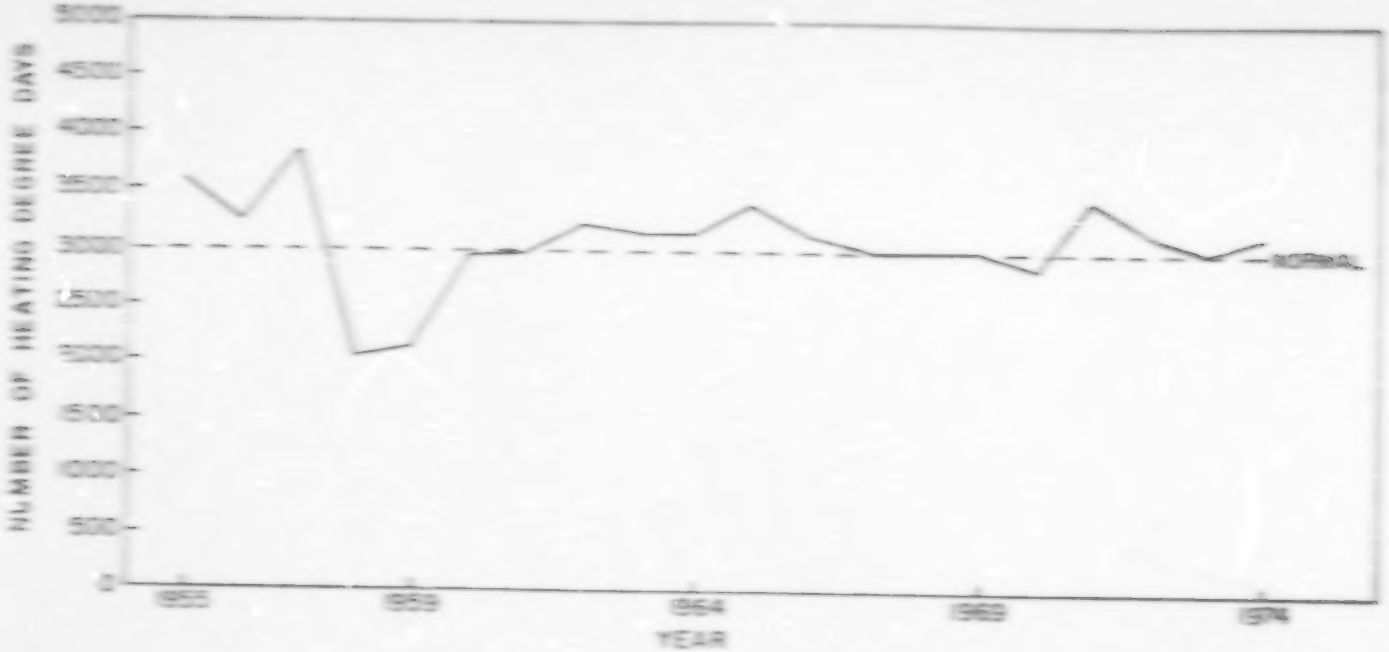


Figure A-4. Yearly heating degree days in San Francisco

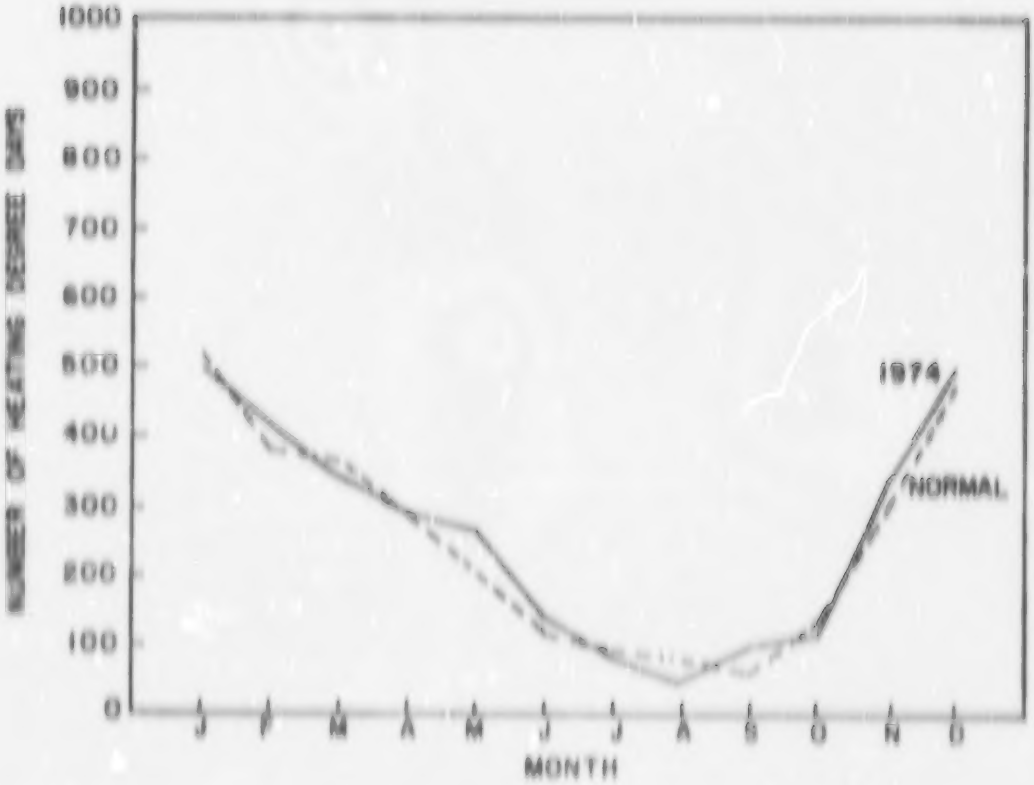


Figure A-5. Monthly heating degree days in San Francisco

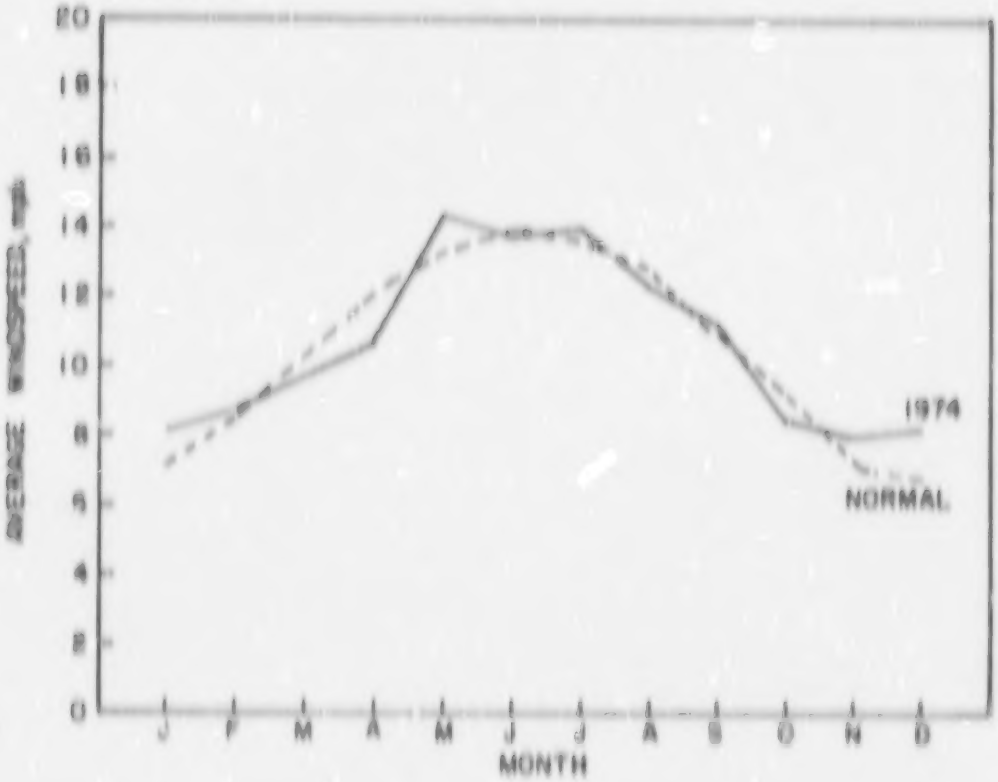


Figure A-6. Monthly wind speed in San Francisco

## APPENDIX B

## PARTICLE CHARACTERIZATION

For most of the study cities members of the GCA study team acquired hi-vol filters from the 1974 filter banks of the cognizant local agencies. In addition, several filter samples for 1974 and selected earlier years were obtained from state and federal filter banks. Although some filters underwent chemical and/or detailed physical analysis, the principal purpose of obtaining filters was to utilize optical microscopy to identify each of the constituents that comprised more than five percent of the particulate mass. The selected filters, which were representative of several different site types and TSP levels within each study area, were returned to a clean room at GCA/Technology Division and carefully inspected for artifacts and evidence of sampler or filter malfunctions.

Each filter was then assigned a randomly generated five digit number which served as the only identifier for the filter sample so that each analyst had no information concerning the city, site, TSP loading or probable local sources associated with the sample. Furthermore, the use of two laboratories for the microscopy, coupled with the randomly generated identifying numbers, permitted a fairly comprehensive quality control program in the form of blind replicate analyses. Since both laboratories utilized more than one analyst, these procedures resulted in as many as four microscopists observing samples from the same filter and, in some cases, the same analyst examining replicate samples from the same filter as many as three times.

The results of this quality control effort, which are presented in Volumes I and II, warn against relying very heavily on the results of any one filter analysis. However, the random match-up between analyst and filter sample should minimize systematic bias in composited results.

Fourteen filters from three sites were selected for analysis in San Francisco and the meteorological data from the San Francisco International Airport for the selected sampling days are summarized in Table B-1. To gain some insight into the contribution of secondary particulates, much of which is too small to be observed by the microscopists, the annual average sulfate and nitrate concentrations for the NASN site are shown in Table B-2. The results for each of the filters submitted for routine analysis are presented in Table B-3. The results for the filters at each site have been averaged to give a composite of the particulate composition as shown in Table B-4. Four filters underwent replicate analyses, and the results are presented in Table B-5.

The composite particulate characterization for all filters from San Francisco that underwent routine analysis, presented in Table B-6, shows that minerals make up a majority of the particulate but do not predominate to the degree as in most other study cities. San Francisco ranked fourth lowest in that category. Of the three sites from which filters were analyzed, Livermore had the highest percent minerals. This site also experienced the highest TSP levels in 1976 and is exposed to nearby dirt parking lots, gravel pits and highway construction.

The most striking result of the filter analyses is the large amount of rubber observed. San Francisco ranked highest of all study cities with a citywide average of 16 percent. The station at 939 Ellis Street consistently had the highest percentage of rubber but the lower overall TSP levels at that site probably inflate a fairly uniform rubber concentration into a higher percentage. If the microscopy results can be used as a reliable distribution of the entire particulate mass, then

the average rubber concentration at this site would be just over 13 $\mu g/m^3$. Likewise at both the Livermore and East San Francisco sites, the concentrations would be about 9 $\mu g/m^3$. This seems to imply a citywide phenomenon rather than localized observations as has been observed in some cities.

The Bay Area Air Pollution Control District performs extensive chemical analyses on the material collected on hi-vol filters. The analyses are not performed on the regular glass fiber filters that are run every sixth day, but on Whatman 41 filter papers which are also run every sixth day but three days displaced from the glass fiber filter schedule. The resulting data, although not directly comparable to the sampling days reported herein, give a very good picture of the concentrations of some chemical constituents of environmental concern. Table 8-7 gives the annual geometric mean concentrations of eight constituents for the three sites from which filters were selected for microscopic analysis. It can be seen that the two sites closer to the salt water (SF9 and SF10) have much higher concentrations of chloride than the Livermore site, as would be expected. SF9 also reports higher levels of lead which is probably the result of the nearby parking garage as well as higher traffic levels.

Table B-1. METEOROLOGICAL DATA ON SELECTED SAMPLING DAYS (SAN FRANCISCO INTERNATIONAL AIRPORT)

| Date | Precipitation, in. | | Wind speed, mph | | Wind direction, deg | |
|---|---|---|---|---|---|---|
| | Day of obs. | Preceding day | Average | Resultant | 3-hour observation | Resultant |
| 2/10/74 | 0 | 0 | 8.8 | - | 310, 100, 300, 280<br>250, 190, 310, 310 | - |
| 4/3/74 | 0 | 0.01 | 11.2 | - | 200, 270, 270, 290<br>290, 100, 20, 310 | - |
| 4/29/74 | 0 | 0 | 14.5 | - | 280, 280, 130, 300<br>300, 310, 310, 300 | - |
| 6/10/74 | 0 | 0 | 13.5 | - | 310, 300, 310, 300<br>300, 320, 340, 330 | - |
| 7/23/74 | 0 | 0 | 13.9 | - | 300, 310, 310, 310<br>310, 310, 310, 310 | - |
| 8/31/74 | 0 | 0 | 12.2 | - | 310, 310, 310, 300<br>300, 300, 50, 310 | - |

Note: 0 = Calm

Sampling time, 1500 to 1500; sampling date recorded as start day.

Average wind speed is average of 3-hour observations.

Table B-2. ANNUAL AVERAGE CONCENTRATIONS OF SULFATE AND NITRATE IONS AT THE SAN FRANCISCO, CALIFORNIA NASN SITE NO. 056860001 ($\mu g/m^3$)

| Year | Sulfate | | Nitrate | |
|---|---|---|---|---|
| | Arithmetic mean | Geometric mean | Arithmetic mean | Geometric mean |
| 1972 | [illegible] | 3.15 | 2.15 | 1.50 |
| 1973 | 3.11 | 3.85 | 3.32 | 1.13 |
| 1974 | 3.11 | 3.90 | 3.31 | 2.70 |

Table B-1a. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN SAN FRANCISCO AND VICINITY (LIVERMORE — NO. 4-11)

| Date | [illegible] | | | [illegible] | | | [illegible] | | | [illegible] | | | [illegible] | | | [illegible] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | [illegible] | | | [illegible] | | | [illegible] | | | [illegible] | | | [illegible] | | | [illegible] | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | | | [illegible] | | | [illegible] | | | [illegible] | | | [illegible] | | | [illegible] | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | | | [illegible] | | | [illegible] | | | [illegible] | | | [illegible] | | | [illegible] | | |
| [illegible] | | | | | | | | | | [illegible] | | | | | | | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | | | [illegible] | | | [illegible] | | | [illegible] | | | [illegible] | | | [illegible] | | |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

Table 5-3a. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN SAN FRANCISCO AND VICINITY (SAN FRANCISCO - NO. SF-5)

Table B-3c. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN SAN FRANCISCO AND VICINITY (EAST SAN FRANCISCO - NO. SF-10)

| Date | 22 July 1976 | | | 21 August 1976 | | |
|---|---|---|---|---|---|---|
| TSP ($\mu g/m^3$) | 75 | | | 102 | | |
| Components | Quantity, tenths | Size range, μm | Avg. size, μm | Quantity, tenths | Size range, μm | Avg. size, μm |
| **Minerals** | (0) | | | (4) | | |
| Quartz | 2 | 5-15 | 20 | 2 | 5-30 | 20 |
| Calcite | 2+ | 5-20 | 10 | 1+ | 2-20 | 10 |
| Feldspars | 2 | 7-60 | 30 | 1+ | 2-60 | 30 |
| Hematite | 1 | 2-10 | 5 | | | |
| Mica | | | | | | |
| **Combustion Products** | (3) | | | (4) | | |
| Soot: | | | | | | |
| Oil | | | | | | |
| Coal | | | | | | |
| Glassy | | | | | | |
| fly ash | | | | | | |
| Incinerator | 2 | 10-80 | 60 | 3+ | 1-60 | 20 |
| fly ash | | | | | | |
| Burned wood | 1 | 30-80 | 30 | | | |
| Burned paper | | | | | | |
| Magnetite | | | | | | |
| **Biological Material** | (1+) | | | (0+) | | |
| Pollen | | | | | | |
| Spores | | | | | | |
| Paper | | | | | | |
| Starch | | | | | | |
| Misc. plant | | | | | | |
| tissue | | | | | | |
| **Miscellaneous** | (0+) | | | (2) | | |
| Iron or steel | | | | | | |
| Rubber | | | | (2) | 20-150 | 70 |

Table B-4. COMPOSITE SUMMARY OF FILTER ANALYSES FOR SELECTED SITES IN SAN FRANCISCO AND VICINITY

| Site | San Francisco No. SF-5 | | Livermore No. A-11 | | East San Francisco No. SF-10 | |
|---|---|---|---|---|---|---|
| No. of filters | 6 | | 6 | | 2 | |
| | Quantity, percent | | Quantity, percent | | Quantity percent | |
| Components | Average | Range | Average | Range | Average | Range |
| Minerals | (53) | 29-56 | (61) | 40-73 | (51) | 39-62 |
| Quartz | 22 | 15-35 | 31 | 20-50 | 15 | 18-19 |
| Calcite | 6 | 2-15 | 6 | 2-12 | 10 | 4-16 |
| Feldspars | 15 | 6-25 | 21 | 10-35 | 17 | 15-18 |
| Hematite | 1 | tr-1 | 1 | 0-1 | 5 | 2-8 |
| Mica | | | tr | 0-tr | tr | 0-tr |
| Combustion Products | (28) | 10-50 | (27) | 18-39 | (36) | 33-51 |
| Soot: | | | | | | |
| Oil | 4 | 0-8 | 2 | 0-6 | 1 | 0-2 |
| Coal | 8 | 0-18 | 12 | 0-25 | 2 | 0-3 |
| Fine soot | <1 | 0-2 | | | | |
| V.V. fine | | | | | 1 | 0-2 |
| Glassy fly ash | 2 | 0-10 | <1 | 0-1 | | |
| Incinerator fly ash | 14 | 0-45 | 13 | 0-30 | 25 | 18-35 |
| Burned wood | | | | | 6 | 2-10 |
| Burned paper | | | | | | |
| Magnetite | | | | | 1 | 0-2 |
| Biological Material | ( 5) | tr-10 | ( 2) | tr-5 | ( 3) | tr-5 |
| Pollen | 2 | tr-5 | 2 | tr-3 | 1 | tr-1 |
| Spores | tr | 0-tr | tr | 0-tr | tr | 0-tr |
| Paper | 1 | 0-1 | <1 | 0-1 | tr | 0-tr |
| Starch | <1 | 0-tr | <1 | 0-1 | <1 | 0-tr |
| Misc. plant tissue | 2 | tr-5 | <1 | 0-1 | 2 | tr-3 |
| Miscellaneous | (25) | 16-35 | (10) | 5-21 | (10) | 0-20 |
| Iron or steel | | | | | | |
| Rubber | 22 | 16-26 | 10 | 5-21 | 10 | 0-20 |
| Salt | 2 | 0-10 | | | | |

Table B-5. **RESULTS OF REPLICATE ANALYSES OF SAN FRANCISCO FILTERS**

| Site | San Francisco - No. SF-9 | | | | | East San Francisco No. SF-10 | | | | Livermore No. A-11 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 10 June 1976 | | | 21 August 1976 | | 21 August 1976 | | | | 10 June 1976 | |
| TSP (μg/m³) | 88 | | | 50 | | 102 | | | | 121 | |
| Laboratory | A | A | B | A | B | A | A | B | B | A | A |
| Analysis | 1 | 2 | 1 | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 2 |
| Components | | | | | | | | | | | |
| Minerals | (110) | (63) | (19) | (50) | (52) | (19) | (75) | (71) | (12) | (40) | (91) |
| Quartz | 15 | 25 | | 20 | | 18 | 30 | | | 20 | 35 |
| Calcite | 8 | 30 | | 5 | | 4 | 30 | | | 4 | 50 |
| Feldspars | 9 | 3 | | 25 | | 15 | 5 | | | 15 | 8 |
| Hematite | 1 | 5 | | tr | | 2 | 7 | | | 1 | 6 |
| Mica | | | | | | tr | <1 | | | tr | <1 |
| Gypsum | | | | | | | 4 | | | | |
| Combustion Products | (50) | (28) | (61) | (27) | (48) | (41) | ( 5) | (69) | (68) | (36) | ( 5) |
| Soot: | | | | | | | | | | | |
| Oil | 5 | 25 | 8 | 5 | 6 | 2 | 5 | 12 | 5 | 6 | 5 |
| Coal | | 1 | | 15 | | | <1 | | | | <1 |
| V.v.fine | | | | | | 2 | | | | | |
| Glassy | | 2 | | | | | <1 | | | | <1 |
| fly ash | | | 53 | | 46 | | | 57 | 63 | | |
| Incinerator fly ash | 45 | | | 7 | | 35 | <1 | | | 30 | |
| Burned wood | | | | | | 2 | | | | | |
| Burned paper | | | | | | | | | | | |
| Magnetite | | | | | | | | | | | |
| Biological Material | ( 5) | ( 5) | (<1) | ( 3) | (<1) | (<1) | (<1) | (<1) | (<1) | ( 3) | (<1) |
| Pollen | 1 | | | tr | | tr | <1 | | | 3 | |
| Spores | | <1 | | | | | <1 | | | | <1 |
| Paper | 1 | <1 | | 2 | | tr | <1 | | | tr | |
| Starch | | <1 | | tr | | | | | | tr | |
| Misc. plant tissue | 2 | 3 | | 1 | | tr | <1 | | | tr | |
| Miscellaneous | (10) | ( 5) | (<1) | (20) | (<1) | (20) | (20) | (<1) | (<1) | (21) | ( 4) |
| Iron or steel | | <1 | | | | | <1 | | | | <1 |
| Rubber | 10 | 4 | | 20 | | 20 | 20 | | | 21 | 4 |

Table B-6. CITYWIDE COMPOSITE SUMMARY OF FILTER ANALYSES IN SAN FRANCISCO

| No. of filters | 14 | |
|---|---|---|
| | Quantity, percent | |
| Components | Average | Range |
| **Minerals** | (52) | 29-73 |
| Quartz | 25 | 15-50 |
| Calcite | 7 | 2-16 |
| Feldspars | 18 | 6-35 |
| Hematite | 2 | 0-8 |
| Mica | <1 | |
| Other | | |
| **Combustion Products** | (29) | 10-50 |
| Soot: | | |
| Oil | 1 | 0-8 |
| Coal | 9 | 0-25 |
| Misc. soot | <1 | 0-2 |
| Glassy fly ash | 1 | 0-10 |
| Incinerator fly ash | 15 | 0-45 |
| Burned wood | 1 | 0-10 |
| Burned paper | | |
| Magnetite | <1 | 0-2 |
| Carbon black | | |
| Other | | |
| **Biological Material** | ( 3) | tr-10 |
| Pollen | 2 | tr-5 |
| Spores | <1 | |
| Paper | <1 | |
| Starch | <1 | |
| Misc. plant tissue | 1 | 0-5 |
| Leaf trichomes | | |
| **Miscellaneous** | (16) | 0-35 |
| Iron or steel | | |
| Rubber | 16 | 0-26 |
| Other | <1 | 0-10 |

Table B-7. 1974 GEOMETRIC MEAN CONCENTRATIONS OF SELECTED PARTICULATE CONSTITUENTS AT THREE BAAPCD SITES

| Constituent | Site | | | | | |
|---|---|---|---|---|---|---|
| | All | | SF9 | | SF10[a] | |
| | No. of observations | Concentration, $\mu g/m^3$ | No. of observations | Concentration, $\mu g/m^3$ | No. of observations | Concentration, $\mu g/m^3$ |
| Cu | 30 | 0.125 | 29 | 0.096 | 11 | 0.120 |
| Pb | 30 | 0.415 | 29 | 0.939 | 11 | 0.498 |
| Mn | 29 | 0.036 | 28 | 0.034 | 11 | 0.025 |
| Zn | 30 | 0.080 | 28 | 0.064 | 12 | 0.111 |
| $NH_4^+$ | 27 | 0.876 | 26 | 0.662 | 7 | 1.150 |
| $SO_4^=$ | 25 | 1.529 | 26 | 3.348 | 9 | 4.896 |
| $NO_3^-$ | 27 | 3.384 | 26 | 2.839 | 9 | 3.326 |
| $Cl^-$ | 27 | 0.795 | 26 | 3.305 | 9 | 2.692 |

[a]Observations from July - December only.